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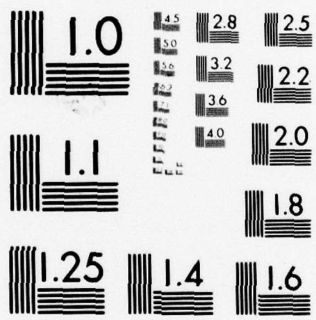

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DIGITAL TERRAIN AND MOBILITY DATA BASES FOR E-FOSS

by

Harold W. West, Daniel Krivitzky
Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

and

Donald D. Randolph
Geotechnical Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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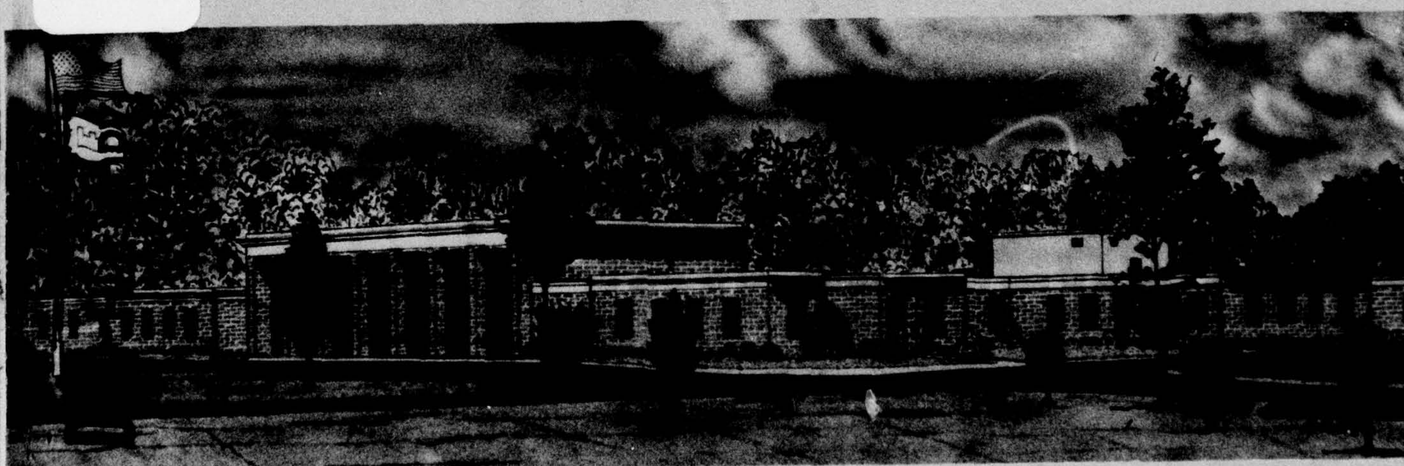

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White Sands, N. Mex. 88002;
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This report describes procedures used by the U. S. Army Engineer Waterways Experiment Station to develop and structure digital terrain and mobility data bases for the CARMONETTE and AMSWAG models. Data bases were constructed for each model using 100-m grid cells or arrays. For the CARMONETTE model, data were developed on roads, topography, vegetation, terrain cover and concealment, and cross-country mobility. The data developed for the AMSWAG model consisted

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20. ABSTRACT (Continued).

of 25 terrain parameters and 9 cover and concealment related parameters. Digital data bases were developed on each of six 1:50,000 quadrangles in the Federal Republic of Germany. These data bases were used by the U. S. Army TRADOC Systems Analysis Activity in support of the Engineer-Family of Systems Study (E-FOSS).

PREFACE

The study reported herein was conducted by the U. S. Army Engineer Waterways Experiment Station (WES), during 1 Nov 77 - 30 Sep 78 for the U. S. Army TRADOC Systems Analysis Activity (TRASANA), White Sands Missile Range, N. Mex., and the U. S. Army Engineer School (ES), Fort Belvoir, Va.

The work was authorized by Mr. Warren Olson, Armored Systems Division, TRASANA, and CPT Norviel R. Eyrich, Directorate of Combat Developments, ES. The Program Manager at TRASANA for the WES E-FOSS work was Mr. Olson.

The procedures and methodology for preparing some of the terrain data for the CARMONETTE VI Model were developed under Department of the Army Project 4A762730AT42, "Design, Construction, and Operations Technology for Cold Regions," Task B/E4 "Information Structuring for Terrain Evaluation," sponsored by the Office, Chief of Engineers (OCE), U. S. Army.

The study was performed by personnel of the Environmental Systems Division (ESD), Environmental Laboratory (EL), and the Mobility Systems Division (MSD), Geotechnical Laboratory (GL), under the supervision of Messrs. H. W. West, Waterway Habitat and Monitoring Group (WHMG), ESD, EL, and D. D. Randolph, Mobility Research and Methodology Branch (MRMB), MSD. The study was under the general supervision of Dr. J. Harrison, Chief, EL, and Messrs. B. O. Benn, Chief, ESD, C. A. Nuttall, MRMB, and E. S. Rush, Chief, MSD. Mr. D. Krivitzky, EL, was responsible for the development of computer programs and data for use with the CARMONETTE War Game Model and Messrs. R. P. Smith, R. B. Ahlvin, and B. R. Wright, MSD, were responsible for development of computer programs and data for the AMSWAG War Game Model. Messrs. Jerry Smith and Al Williamson, Data Handling Branch, MSD, were responsible for development of the CARMONETTE data on roads. This report was prepared by Messrs. West, Randolph, and Krivitzky.

COL N. P. Conover, CE, and COL J. L. Cannon, CE, were Directors

of WES during the study and report preparation. Mr. F. R. Brown was Technical Director.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	25.4	millimetres
miles per hour (U. S. statute)	1.609344	kilometres per hour

DIGITAL TERRAIN AND MOBILITY DATA BASES FOR E-FOSS

PART I: INTRODUCTION

Background

1. The U. S. Army TRADOC Systems Analysis Activity (TRASANA), White Sands Missile Range (WSMR), New Mexico, and the U. S. Army Engineer School (ES) have developed a combat developments study plan entitled "Engineer-Family of Systems Study (E-FOSS)" to determine the requirements for and the utilization of combat engineer assets that will maximize the engineer contributions for winning the "first battle" of the next war. The analytical study is structured to identify deficiencies or gaps in combat engineer capabilities and develop a plan to eliminate them. If the combat engineer system is not organized, trained, and equipped to provide maximum support to other members of the combined arms team, the maximum force effectiveness of the team cannot be fully realized.

2. The E-FOSS addresses combat engineer organizations operating in the V Corps area in the Federal Republic of Germany (FRG) and will include the current organization and organizations synthesized through analysis. Current doctrine, training, equipment, and material items under development (e.g. SLUFAE, UET, FAMECE, and Bridging) are considered in the overall study.

3. In support of the E-FOSS, TRASANA and other agencies have selected several computer models that will be used for determining the effectiveness and costs of the combat engineer system as it operates within the Corps area. Two computer models have been identified for use in the E-FOSS: CARMONETTE VI and the AMSWAG* combat simulation models. Other models are being studied by TRASANA for possible use in the overall system analysis study.

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* Input data prepared by the U. S. Army Engineer Waterways Experiment Station (WES) for the E-FOSS can also be accepted by the TRACOM or DYNTACS combat models.

4. Realistic terrain data are needed for the two combat simulation models because the types of engineer equipment that must be used on the battlefield have their own terrain sensitivities. Further, realistic consideration of the terrain conditions in all Army operation studies, such as E-FOSS, is regarded by the Department of Defense to be significantly important. If realistic terrain conditions, as influenced by weather conditions, can be modeled and used with predictive performance models, it can be determined ahead of time what the limitations are on the equipment within the terrain area(s) of interest. These predictions then can be used as a basis for reconfiguring or redesigning engineer equipment to provide improved performance on the battlefield.

Purpose and Scope

5. The purpose of this report is to document the procedures used by WES to develop and structure the digital terrain and mobility data bases for the CARMONETTE and AMSWAG models. A data base was constructed for each model using 100-m grid cells or arrays. For the CARMONETTE model, data were developed for the following parameters:

a. *Road classification* (Code) and vehicle road speeds (mph).

b. Topographic elevation, m.

c. Height of vegetation, m.

d. Terrain concealment (percent of 3-m-tall target height).

e. Terrain cover (percent of 3-m-tall target height).

f. Cross-country mobility (Code) and vehicle cross-country speeds (mph).

The vehicle speeds both on roads and for cross-country terrain were determined for nine vehicles including the M113A1 Extended, T62, BMP, M113A1, BRDM-2, XM1, CMICV, M60A1, and FT1.*

6. The data developed for the AMSWAG model consisted of the 25 terrain parameters listed in Table 1, plus the 9 cover and concealment related parameters shown in Table 2. The parameters listed in Table 1

* Unnamed vehicle.

are also those that are required for use with the Army Mobility Model (AMM-74X) (Jurkat, Nuttall, and Haley 1975; Nuttall and Randolph 1976) to predict cross-country speeds for different military vehicles.

7. Data were developed according to the standard input formats (General Research Corporation 1974) for the two models, except for one modification made for the CARMONETTE cross-country mobility codes to allow better comparison of the vehicle speeds used in the CARMONETTE model with those predicted by the AMSWAG model (a discussion of this code modification is given in paragraphs 41-44).

8. The region within the FRG that was selected by TRASANA and ES for conduct of the E-FOSS was an area covered by six 1:50,000 quadrangle maps (Series M745): these include Fulda (L5524), Alsfeld (L5320), Lauterbach (L5322), Hunfeld (L5324), Neukirchen (L5122), and Bad Hersfeld (L5124). The relative locations of these quadrangles in the FRG are shown in Figure 1.

PART II: DESCRIPTION OF DATA PREPARED FOR THE CARMONETTE MODEL

9. The kinds and resolution of data required by the CARMONETTE model were not available from any ready source and, therefore, had to be developed by WES for the E-FOSS area. The WES procedure for doing this consisted of preparing special overlays to each 1:50,000 quadrangle map depicting the needed terrain factors. If time and funding permit, it is normally advantageous to use considerable ground truth data and literature data in the development of these overlays to ensure that all the parameters are mapped accurately. However, in this study, the required terrain maps had to be prepared within a time frame that did not allow the collection of ground truth data. Therefore, it is important that the users of the E-FOSS digital data understand that some of the individual terrain characteristics assigned to a particular grid square may not reflect the actual terrain conditions on the ground. However, the prepared data bases will permit the effects of terrain to be considered in a consistent and realistic way for the current E-FOSS and other current cost and effectiveness analyses (COEA's) presently being conducted by the Army Agencies. The data prepared by WES for use with the CARMONETTE combat model are discussed in detail in the following paragraphs.

Data Format

10. The terrain and mobility data developed for use with the CARMONETTE combat model on each of the six quadrangles are contained on two magnetic tapes. Tape 1 contains the 100-m grid data for the six terrain parameters (paragraph 5) and tape 2 contains the vehicle cross-country speeds by slope class for each of nine vehicles for both dry and wet season terrain conditions.

11. The format for tape 1 is given in Figure 2a. One 36-bit word contains data on all six parameters for one 100-m grid. The total number of 36-bit words per record and the total number of records for each 1:50,000 map quadrangle are as follows:

1:50,000 Quadrangle Map	Number of Words/Record	Number of Records Per Tape
Fulda	243	225
Lauterbach	237	224
Alsfeld	236	223
Hunfeld	240	225
Neukirchen	236	224
Bad Hersfeld	237	225

The format for tape 2 is shown in Figure 2b and contains the dry season and wet season cross-country vehicle speeds by 13 specified terrain slope values (0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, and 60 percent).

12. A rectangular data array composed of 100-m grid cells was constructed over each of the six 1:50,000 map quadrangles (Figures 3-8). The reference (or origin) for the grid array is the UTM Coordinate System as noted in the lower left corner of each map (Figures 3-8). In constructing the data array, a decision had to be made as to whether or not a generated 100-m grid was considered inside or outside the boundaries (or edges) of the 1:50,000 map. If more than 50 percent of a generated grid square was outside the edge of the map, then the grid square was considered completely outside and was assigned a -1 code. If 50 percent was inside, then the grid square was included as part of the data array. The data arrays for each map sheet were generated independently of each other.

Road Classification and Vehicle Road Speed Data

13. Road data consisted of two parts: the first part being classification of the road type and the second being a set of speeds for each of nine military vehicles for the different road classifications. Each of these is discussed in the following paragraphs.

Road classification data (code)

14. The various road types on the AMS 1:50,000 (M745 Series) topographic maps (see also Figure 9) were grouped first according to

three main categories. Primary roads were those designated as autobahns, dual highways, trunk roads, main roads, and secondary roads in the legend of the 1:50,000 scale map; secondary roads were those designated as light surface roads and roads; and trails were those designated as farm and forest roads.

15. Lineations of each of the three road types were then traced on a separate sheet of paper along with tic marks to denote the corners of the topographic map and the corners of the proposed digital data array. The lineations were each transferred to a separate scribe-coat using a 0.015-in.* scribe. The scribe-coat served as a photographic negative and was used to produce a print by conventional photographic printing techniques. The print depicted roads of a given type, map corner tic marks, and digital data array tic marks as black lines and all other areas as white. Figures 10-12 are examples of the ones produced for the Hunfeld 1:50,000 map. The three prints were then photographically reduced in size to 25 percent of the originals to permit digitizing on an Optronics International, Inc., photomation mark scanner/digitizer. (Appendix A contains a description of the scanner/digitizer.) The resulting film transparency depicted roads and tic marks as clear (transparent) and all other areas as black (opaque).

16. The film transparencies were then placed one at a time on the high-speed drum scanner/digitizer and each 50-μm (10- by 10-m area on the ground) area on the transparency was tested and coded for the presence of a white spot (no road) and a black spot (a road or corner tic marks).

17. The resulting three sets of digital data (i.e. one each for primary, secondary, and trails) were then geometrically adjusted so that pixels along the scanner/digitizer x-axis conformed accurately to the map north-south, and pixels along the scanner/digitizer y-axis conformed accurately to the map west-east. Adjustments were accomplished by a pair of computer programs, ACCLIN and PØLY20, that are described in detail in Kennedy and Williamson (1976). Computer program ACCLIN is an

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* A table of factors for converting U. S. customary units of measurement to metric (SI) can be found on page 4.

adaptation of a set of equations developed by Wong (1974) for transforming the coordinates of transfer points into a calibrated system. Coefficients required for operation of ACCLIN are derived from the program PØLY20, which was developed by Wong to determine the coefficients of a best-fitting polynomial for the x- and y-coordinates separately by the method of simultaneous least square adjustment, the x- and y-translation errors, and rotational errors. Transfer points used to make the required geometric adjustments of the road data were the four map corner tic marks. In addition, the map tic marks were used to make minor adjustments to the overall size of the digitized area.

18. After geometric adjustments were completed, the tic marks and the border pixels around the digitized maps were no longer required. In this step these were removed from the data set.

19. At this point, a completed data set had been prepared for primary roads, secondary roads, and trails. Each data set had been geometrically adjusted and the size corrected where necessary so that each data set was described by the same number of pixels in x and y and the value of each pixel in any one data set could be located with respect to its corresponding pixel value in each of the other two data sets.

20. The next step in the procedure was to (a) check each pixel of each of the three data sets and determine if the pixels contain a road or not and (b) produce an output code that identified the presence of a primary road, secondary road, trail, or any one of the four possible combinations of these three.

21. The output tape that resulted from this process contained a record of the roads in each 10- by 10-m area identified by the following class codes:

Class Code	Road Type(s)
0	No road
1	Primary road
2	Secondary road

(Continued)

Class Code	Road Type(s)
3	Trail
4	Primary and secondary roads
5	Primary road and trail
6	Secondary road and trail
7	Primary and secondary roads and trails

Since the desired road data for CARMONETTE was a digital tape on which roads in each 100- by 100-m area of a map were identified, it was necessary that the 10- by 10-m data be generalized. Generalization was accomplished by "blocking" the 10- by 10-m gridded data into 10 by 10 pixel blocks. Each block then represented an area on the terrain surface 100 by 100 m in size.

22. The appropriate class code for each block was determined after considering the class code of each 10- by 10-m pixel comprising the block. If all areas in a block were the same, then the class code for the block was the code for all the areas comprising the block. But, if only one area in the block had a code different from that of the remaining areas in the block, then the class code for the block was changed to reflect the class code of the kinds of areas. For example, if all areas in a block were class 2 areas (i.e. secondary roads), then the block would be identified as a class 2 block. On the other hand, if one of the areas had been a class 5 area (i.e. primary road and trail), then a class code of 7 was assigned to the 100-m block indicating that the block contained primary and secondary roads and trails. This coding process is illustrated in Figure 13.

Vehicle road speeds (mph)

23. The second part of the road data consists of speed data for the different military vehicles on the three types of roads. Speed data for each of the nine E-FOSS vehicles (M113A1 Extended, T62, BMP, M113A1, BRDM-2, XM1, CMICV, M60A1, and FT1) were estimated from vehicle predictions on similar roads for both dry and wet road conditions. The predicted road speeds were based on a vehicle traveling one third of the time upslope, one third downslope, and one third parallel to the designated

slope value within each grid cell. Both road surface roughness (i.e. for trails) and road center-line curvature effects were considered; however, soil strength effects were not considered for the trails. The road speed data were determined for 4, 6, and 10 different classes of road slope for primary, secondary, and trails, respectively, and are presented in Tables 3-5.

Topographic Elevation Data (m)

24. The ground surface elevation values provided for each 100-m grid within the CARMONETTE data array were determined by calculating an arithmetic mean of the 64 elevation values spaced at 12.5-m intervals on the Defense Mapping Agency Topographic Center (DMATC) data tapes. The equation used by WES for the calculation of the mean values was:

$$\overline{E} = \sum_{i=1}^{64} \frac{E_i}{64} \qquad (1)$$

where

$\overline{E}$ = mean ground surface elevation, m

E_i = elevation at a 12.5-m grid location on the DMATC data tapes, m

25. The 100-m arithmetic mean elevation values were considered a fairly good representation of the terrain surface as suggested by the computer-drawn perspective (Figure 14) of the topographic surface within the Hunfeld 1:50,000 quadrangle. The data base used for this plot was the 100-m elevation values calculated by Equation 1.

Vegetation Height Data (m)

26. The vegetation height data for the CARMONETTE data array were obtained by using the topographic maps and a limited amount of ground truth data collected by a WES field team during past field programs (Table 6). The 1:50,000 topographic maps were used by WES to specify the areas within each quadrangle covered by vegetation. Ground truth

data and literature data extracted from the references were used to estimate vegetation heights, as of the year 1978, within each of the delineated areas.

27. Figure 15 is a portion of a Calcomp plot that depicts the areal extent of the vegetation within the generated Hunfeld quadrangle CARMONETTE data array. The estimated heights within each vegetated area are also labeled on the example plot.

28. It is emphasized that only very general vegetation height data were developed for this study and therefore it is highly desirable to update this part of the total data base as soon as additional data are available. For example, the Terrain Analysis Center, Fort Belvoir, Va., is doing a terrain study of the V Corps Area in which vegetation height data will be mapped for each of the six E-FOSS quadrangles. These data, together with ground truth data collected by WES field teams in July and August 1978, could provide the information for constructing a superior data base for vegetation.

Terrain Concealment Data

29. The CARMONETTE target concealment data were determined by comparing a 3-m-tall target resting on the ground with the height of the vegetation (as described in paragraphs 27-28) at each 100-m grid location. If the vegetation height was greater than the target height at a grid location, the concealment was considered to be 100 percent (see Figure 16a). If the vegetation height was less than the target height, the concealed portion of the target was expressed as a percent of the total target height and placed in the appropriate class range for target concealment (see Figure 16b). Seven codes were used to represent terrain concealment of the target as given below:

Code	Percent of 3-m-tall Target Height that is Concealed by Terrain (i.e. Vegetation)
1	0-15
2	>15-30
3	>30-45

(Continued)

Code	Percent of 3-m-tall Target Height that is Concealed by Terrain (i.e. Vegetation)
4	>45-60
5	>60-75
6	>75-90
7	>90-100

It is noteworthy here that in the CARMONETTE combat model if "terrain cover" (described in paragraphs 30-38) was equal to 100 percent for a given 100-m grid square, then the concealment of the target at that grid square should also be considered to be 100 percent. Using the procedure described above to determine concealment there are some grid squares within each quadrangle that show terrain cover at 100 percent and concealment at some value less than 100 percent; an additional step is needed to ensure that all grid squares showing cover at 100 percent also show concealment at 100 percent. This final step was accomplished by TRASANA prior to using the WES data as input to the CARMONETTE model.

Terrain Cover Data

30. The CARMONETTE cover data are based on a target height of 3 m resting on the ground surface, a weapon range of 1000 m, and a weapon height of 2 m above the ground surface. To arrive at an estimate of terrain cover for each of the six E-FOSS quadrangles, the WES Terrain Shielding Model (West, Doiron, and Parks 1974) and the 100-m ground elevation data discussed in paragraphs 24-25 were used as described in the following paragraphs.

31. Cover predictions were initially obtained for 50 sites chosen randomly on each of the six quadrangles. The x- and y-coordinate locations of the 50 randomly selected sites are given in Table 7. The coordinate system origin was the upper left corner for each map of the six E-FOSS maps. A brief description of how the WES Terrain Shielding Model calculated cover for the 50 selected sites is given below.

32. Terrain cover (or shielding), as calculated by the model, is defined as follows (see Figure 17): a point on a vertical target is said to be covered or shielded if the straight line path between a

specified weapon position and the point on the target is obstructed by the terrain surface. If a point on the target is shielded, the probability of shielding P_s of the point on the target equals 1; if the point is not shielded, the probability of shielding is zero. In the model if any one point on the target is shielded or visible, the height interval represented by that point is said to be also shielded or visible. The location of each point on the target is considered to be at the top of the interval (see Figure 17).

33. To determine whether or not a specified straight line path is intercepted by the terrain, an elevation profile along a line between the target position and the weapon position was calculated using the 100-m gridded elevation data (paragraphs 24-25) that were generated in the study. The profile was determined by calculating the elevation of selected points along a line connecting the horizontal positions of the target and weapon position. The elevation of each point along the specified profile was then calculated using the following equation and the elevation data arrays (paragraphs 24-25) that were generated for the E-FOSS.

$$z_{i,j} = \sum_{k=1}^{4} \frac{z_k}{R_k^2} \Bigg/ \sum_{k=1}^{4} \frac{1}{R_k^2} \qquad (2)$$

where

$z_{i,j}$ = the elevation at the $(i,j)^{th}$ grid position within the CARMONETTE data array

z_k = the elevations of the four nearest neighbors of grid points to the specified position (i,j)

R_k^2 = the square distances of each k^{th} data point from the $(i,j)^{th}$ grid point

After the elevation of each selected point along the extracted profile is calculated, these elevations are compared with elevations along each projected path at the same distance. If the elevation of any one point along the ground profile is greater than the corresponding point along the specified path, the path is said to be intercepted by the ground

surface, and the interval represented by that point of the target height is shielded or covered.

34. For each of the 50 selected target positions for which cover calculations were made, individual weapon positions were specified along a circle of radius 500, 1000, 2000, and 3000 m from the target (Figure 18). The number of weapons positions was determined by the model according to the following equation.

$$N_t = \frac{2\pi R}{s} = \frac{R}{10} \quad (3)$$

where

N_t = total number of weapon positions for each circle of radius R

R = radius of circle (or weapon range), m

s = uniform spacing of weapon positions along the circumference of a circle of radius R and considered to be equal to 20π, m

35. The Terrain Shielding Model calculations for one grid position, a variable height tall target, and four ranges (500, 1000, 2000, and 3000 m) for the Hunfeld quadrangle are given in Table 8. The only cover value from Table 8 used by WES for the final CARMONETTE data array is the value for a target height of 300 cm and a range of 1000 m. On Table 8 this value is 0.694 or 69.4 percent. This cover value says that at grid square $x = 201$ and $y = 215$, the average terrain cover offered to a 3-m-tall target from direct fire weapons positioned along a circle of range 1000 m would be 69.4 percent. That is, the grid square has protection afforded to it by the terrain 69.4 percent of the time, considering weapons firing from all specified azimuthal directions.

36. The cover predictions for each of the 50 sites were used as control on the subjective mapping of cover for each of the respective quadrangles. The following terrain cover codes were used.

Codes	Percent of 3-m Target Height that has Terrain Cover
1	0-15
2	>15-30

(Continued)

Codes	Percent of 3-m Target Height that has Terrain Cover
3	>30-45
4	>45-60
5	>60-75
6	>75-90
7	>90-100

37. The cover maps that were produced were then digitized and used with various computer programs to produce 100-m grid data containing the coded terrain cover data. These data were then transferred to the master magnetic tape containing the other five data types.

38. The above subjective procedure used by the WES for determining cover should be replaced with an analytical procedure that allows calculation of a cover value for each respective 100-m grid square. The particular procedure can presently be handled with the WES Terrain Shielding Model; however, calculating a cover value for each of approximately 55,000 grid squares is now too costly. A new, less costly procedure for target cover determination should be developed and used in future studies.

Cross-Country Mobility and Vehicle Speed Data

Cross-country mobility (code)

39. In previous studies the cross-country mobility input data for the CARMONETTE VI combat model (General Research Corporation 1974) have consisted of three codes describing the mobility within each 100-m grid. These three codes (1, 2, or 3), representing good, fair, or poor terrain (and mobility) conditions, have been usually estimated from the in situ soil condition and surface roughness conditions within the area.

40. In the E-FOSS, a consideration was given to the development of mobility data that would be more closely related to that which was predicted by the AMSWAG combat model. Since the AMSWAG model uses detailed terrain data for the prediction of mobility conditions in terms of vehicle speeds, it was felt that these data should be studied to

determine how the current three codes could be changed to provide for a more realistic description of mobility.

41. Since AMSWAG uses the same terrain data (Table 2) that is required for the Army Mobility Model (AMM), it was decided that the AMM could be used as a basis for determining the minimum number of terrain codes that could be used in place of the total number of mapped terrain codes (i.e. coded terrain patches normally used with the AMM). The following procedure was used by WES for the sensitivity analysis.

a. Step 1: The AMM was first used to predict speeds for nine E-FOSS vehicles for all mapped terrain factors except soil strength and slope within the Fulda quadrangle area; that is, soil strength was considered to be $\geq$300 RCI (rating cone index) and terrain slope was considered to be equal to 0 percent. Therefore, the predicted vehicle speeds were based upon all other mapped terrain factors shown in Table 1. A total of 3500 predictions were made for the mapped terrain conditions within the Fulda quadrangle area.

b. Step 2: A comparison of the predicted speeds was then made to determine which two vehicles would best represent the overall speed performance predictions for all nine vehicles. The two vehicles selected as a result of this analysis were the BMP and M60A1.

c. Step 3: The 3500 mapped terrain patches (or codes) for the Fulda quadrangle were then recoded according to six selected classes of speeds that were predicted for the BMP and M60A1 vehicles. These six codes of vehicle speeds were as follows:

Code	Speed Classes Criteria
1	Both predicted vehicle speeds <3 mph
2	Either vehicle speeds <3 mph
3	Both vehicle speeds $\geq$3 mph and <15 mph
4	One vehicle speed $\geq$15 mph; one vehicle speed <15 mph and $\geq$3 mph
5	Both vehicle speeds >15 mph and <25 mph
6	One vehicle speed $\geq$25 mph; one vehicle speed $\geq$15 mph

This process produced a new coded cross-country terrain map that was independent of soil strength and terrain slope.

d. Step 4: The fourth step in the process was to include the

effects of soil strength so that the resulting cross-country mobility data (codes) could be used for predicting vehicle speeds for both wet and dry terrain conditions. This step was accomplished by assigning a soil strength class(es) that was considered representative of the distribution of wet soil strength that occurred within each of the six assigned speed codes. This resulted in a total of 15 terrain codes for mapping cross-country mobility as shown in Table 9.

e. Step 5: Since the areal terrain mapping work had made provisions for delineating urban areas, it was necessary that a code be also used for these areas. As a result code 16 was selected to depict mobility in urban areas.

42. After going through the above steps, it was decided that a comparison of the overall speed results should be made using the 16 new trafficability codes, the 3 mobility codes representing good, fair, and poor terrain conditions that had been previously used by CARMONETTE model users, and the detailed 3500 terrain or mobility codes that were generated for use with the AMM. This comparison is shown in Figures 19 and 20 and depicts the percent of the area of the Fulda quadrangle with an average speed of a designated value. Predictions are for the M60A1 and BMP vehicles as evident by these graphs. The curve using 16 mobility codes tends to follow very closely with the curve represented by 3500 codes. The curve using only 3 mobility codes tends to produce much higher speeds than produced by the 16 and 3500 codes.

Vehicle cross-country speeds (mph)

43. The AMM was used to predict the speed of each of the nine E-FOSS vehicles (M113A1 Extended, T62, BMP, M113A1, BRDM-2, XM1, CMICV, M60A1, and FT1) in each of the mapped 15 cross-country codes. Predictions were obtained for both wet and dry terrain conditions for each of 13 slopes of 0, 5, 10, 15, ...60 percent. It is noteworthy that these predictions are only for level (0 percent slope) and upslope terrain conditions. No downslope predictions were required for CARMONETTE; however, the speeds predicted for zero slope are considered maximum safe speeds, precluding the need for predicting downslope speed values.

44. In order to predict vehicle speeds with the AMM, soil strength values that were representative of both dry and wet conditions were

necessary. For the wet conditions the midpoint of the soil strength class range (see Table 9) was used, and for the dry conditions the original value mapped by WES for the AMM was used. The soil strength values for the 15 mobility codes are given Table 10.

45. An example of the speed predictions that were obtained for the M113A1 vehicle is given in Table 11. Data of this type were generated for all E-FOSS vehicles and shown on magnetic tape according to the format in Figure 2b.

PART III: DESCRIPTION OF DATA PREPARED FOR THE AMSWAG MODEL

Data Base Format

46. The data developed by WES for the AMSWAG combat model consisted of the 25 terrain factors listed in Table 1, the cover and concealment related data on 9 parameters shown in Table 2, and the vehicle characteristics data of each of the 9 E-FOSS vehicles shown in Table 12. The format of the AMSWAG model input data was the standard format and was in the form of card images. The format for the standard data deck (4) for the terrain data is given in Table 13, and the format for the standard data decks (5 and 6) for the cover and concealment related data is given in Table 14. The format for the standard data deck (14) for the vehicle characteristic data is given in Table 15.

Terrain and Mobility Data

47. The terrain and mobility data prepared for the AMSWAG model contains the same terrain description as required by the AMM. A description of the data base procedures used in preparing these data is briefly described below.

48. The AMM (Jurkat, Nuttall, and Haley 1975; Nuttall and Randolph 1976) predicts speed of a given vehicle in a given nominally homogeneous patch of off-road (areal) terrain. A patch of areal terrain requires specification of 25 descriptors (Table 1) or numbers.*

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* The complete terrain data include alternative values for some factors, which reflect seasonal difference, so that the number of values per terrain unit that constitutes maps is larger. Specific values are selected at run time by specification of appropriate scenario factors. In addition, when, as is normally the case, the predictions are to be aggregated in statistical form or output in map form, data on percentage of area occupied or geographic location of each terrain unit are required at the conclusion of all single-terrain-unit prediction runs. These additional data, however, are not a part of the basic terrain data base used by AMM per se.

49. The kinds and degrees of resolution of data required are not found in any conventional sources, especially for areas large enough for the conduct of meaningful mobility studies; therefore, special maps containing the required data must be prepared. This is done by consulting data sources on the area in question and inferring from their total informational content a series of specific values for the mobility factors needed by AMM.

50. The maps, produced by inferring the required quantitative mobility terrain data for each 100-m grid square from available qualitative data describing the square, are termed study maps. No claim can be made that the specific set of mobility terrain factor values assigned for a given grid square on the map will in fact be found in that square on the ground. What can be claimed for the values is that they are wholly consistent with the available data; that is, if the map shows a forest at some grid square, there will be depicted at that grid square in the mobility data a forest that is reasonable for the climate, site, and cultural influences of the area. Again, if the map shows a specific soil type and slope, the soil strength assigned at that square will be consistent with the best information as to what that strength might be, based on soil type, drainage features, land-use practices, and climate.

51. The assigned values for mobility factors are subject to errors from two sources. First, the initial mapped data, whether it be on the topographic map or one of the other basic data maps, may be in error; for example, the forest that is shown on the map may have been cut down since the map was printed. Second, the assignment of quantitative values from the available qualitative information may be considerably in error because of limitations in correlation procedures. It can be asserted, however, that the process will result in a map that is highly representative of the levels and areal distribution of all major mobility influences throughout the area that it purports to depict and is, therefore, suitable for purposes of such studies as E-FOSS. The maps are not considered to be suitable for tactical use (although they might well be better than anything else available at this time).

52. The inferential process for developing areal terrain unit maps

begins by assembling, in map form, available information on many physical aspects of the area. (Soils, surface geology, and gross vegetation maps plus the best available topographic maps were used for the E-FOSS study area.) Numeric codes are established for all information in the legend of each map. By overlaying the several maps at a common scale, they are consolidated into a single map with appropriately expanded legend information. This step is currently implemented in the computer. To do this, discrete areas defined on each basic map are delineated in a manually prepared overlay and by the associated legend information in coded form. In the case of topographic maps, information density is so great that two overlays were made, one to extract basic slope data and a second to extract all of the extensive land-use and other useful information that is overprinted on the contours. In some cases, digitized elevation data were available from DMATC for portions of the E-FOSS study area (see paragraphs 65 and 66) and were used with computer program SLOPEMAP (Struve 1977), which developed the slope (data). Figure 21 illustrates a coded land-use map, slope map, soils map, vegetation map, surface geology map, and terrain unit map, and Table 16 shows the legend for each of the terrain factor maps. The coded legend of Figure 21 picks up all information in the original map legend for each discrete area.

53. Boundaries between differently coded areas on the separate manual overlay are defined by a series of x- and y-coordinates automatically generated by a manually operated digitizing line-follower and recorded with the codes on a magnetic tape. Computer routines convert these data to a new map, stored as a computer array, in which each discrete area is approximated by a number of squares of 100-m size and each square is associated with the appropriate basic legend data in coded form.

54. Upon completion of the line-follower operation for a given portion of the map, the data tapes are read by an appropriate computer program and replotted on a computer-controlled x- and y-plotter for comparison with the original map. Corrections are made at this time by retracing and redigitizing the boundaries as necessary.

55. When the manual overlay of data for all individual maps of

areal aspects of the terrain is corrected and edited, the individual maps are overlaid in the computer (by means of various routines) to produce a final consolidated map (Figure 22) and corresponding extended legend (Table 17). New patches may be defined at this time by the areal intersections of patches from two or more of the overlaid maps. The composite map is stored in two computer arrays, one that identifies each square with a terrain unit and a second that gives the composite legend information for each terrain unit. Subsequent manipulations to assign terrain factor values are all done with the legend information array only.

56. At this stage of the process, the map consists of a mosaic of small areas (Figure 22) within each of which all descriptors of land use, slope, soil, surface geology, and vegetation are identical. These areas are logical area terrain units or patches by basic definition and, therefore, represent only one set of mobility factor values.

57. In the next step, the composite qualitative legend information for each patch is interpreted to assign a reasonable, internally consistent set of quantitative mobility terrain factor classes to the patch. This is done by examining appropriate subsets of the qualitative information and inferring from each class values for specific single-terrain factors or sets of values for factor families. Interpretation is based on supporting data and reasonable assumptions about the association of specific mobility factors with the quantitative/qualitative descriptors in the legend, under the influence of prevailing cultural practices and climate. The methods used to translate the data from the data type given in Table 16 to the mobility terrain factors are discussed below.

Soil type data

58. The translation from soil type classes described in Table 1 to those required in the AMM is given in Table 18. The translation from the soil type classes given in Table 1 to the soil group numbers required for the soil moisture prediction model are given in Table 19.

Soil strength data

59. Of particular criticality to vehicle performance in the hierarchy of terrain factors is the soil strength cone index (CI) for sand or rating cone index (RCI) for other soils assigned to a given patch,

once the patch is defined by its prevailing slope and the qualitative descriptors from the legend of the source maps. These assignments (one for each of four soil moisture conditions) are based on predictions made with the WES model (Smith and Meyer 1973) for predicting soil moisture and strength (SMSP). The SMSP uses the soil type classification (according to the Unified Soil Classification System), the drainage situation in which that soil is found, and the daily rainfall history to predict day-by-day soil moisture content in the soil layers critical to vehicle operation and the resulting soil strength in terms of CI or RCI.

60. In applying SMSP in the E-FOSS study, long-term rainfall records of a reporting weather station considered representative of each quadrangle area were used. From these records, a single sample day-by-day rainfall history for a full year was generated for each area, which duplicated the recorded long-term average rainfall statistics for the selected station in terms of yearly average, monthly average, and monthly days with more than or less than specified amounts of rainfall. These synthetic records were used as rainfall inputs for each soil type and each drainage condition recognized by SMSP (Tables 20 and 21) to produce a series of 1-yr-long records of corresponding soil strengths in the 0- to 6-in. depth layer. Samples of typical records for the E-FOSS study area are shown in Figures 23 and 24. The soil type-drainage situation to which each refers is given in terms of codes used in the model as shown in Table 20.

61. To approximate the not uncommon occurrence of especially wet years, a second set of predictions was made for each area by simply increasing daily rainfall in the sample day-by-day record by 50 percent throughout the full year.

62. From these sets of predictions, four soil strength classes were chosen for each soil type-drainage situation. The wet season soil strength is the mean soil strength during the 30-day period of normal rainfall that results in the least soil strength. Dry season soil represents the 30-day period in which soil strengths are highest. Average season soil strength is the mean strength during remaining periods. Finally, a wet-wet season soil strength is assigned from the

wet year predictions on the basis of 10 consecutive days during which the soil strength is least.

Slope data

63. Slope magnitude data were determined by two procedures. For the first two E-FOSS quadrangles (L5524 and L5324), slope magnitude data were developed by using a template and manually determining the slope from the 20-m contour lines on the two 1:50,000 topographic maps; for the remaining four quadrangles (L5320, L5322, L5122, and L5124), the computer program SLOPEMAP (Struve 1977) was used to generate the slope magnitude data. The elevation data used with SLOPEMAP were the calculated 100-m elevation values as discussed in paragraphs 24 and 25. It is noteworthy that the slope direction for a particular 100-m grid cell was not determined. In the AMM, speed predictions for a grid cell are predicted considering a vehicle traveling one third upslope, one third downslope, and one third parallel to the slope (zero slope).

64. Slope classes used for the E-FOSS were the eight slope classes given in Table 22 and summarized below:

Class	Slope Range, percent
1	0 - <2
2	2 - <5
3	5 - <10
4	10 - <20
5	20 - <40
6	40 - <60
7	60 - ≤70
8	>70

Obstacle data

65. The AMM requires the obstacle approach angle, obstacle magnitude, obstacle width, obstacle length, obstacle spacing, and obstacle spacing type (Table 1). A set of obstacle factor descriptions (Table 23) which were associated with types of obstacle found in forest, cultivated fields, etc., was estimated from terrain data collected in other areas of similar land uses in the FRG. The types of obstacles included were

logs, stumps, ditches, boulders, walls, etc. Land use and slope were then related to the type and size obstacle for a terrain patch (Table 24). The factor value associated with each obstacle factor class is given in Table 22.

Surface roughness data

66. Measured data from other geographical areas were also used to establish ranges of root-mean-square elevation associated with certain land uses and slopes and these ranges of root-mean-square were sometimes further restricted when associated with given soil type and surface geology types as shown in Table 25. Surface roughness factor values associated with each factor class are given in Table 22.

Vegetation data

67. The AMM requires a stem diameter-stem spacing distribution for each terrain patch (Table 1). Based on the vegetation data from other areas, a series of such density curves consistent with the climate, forest types, and forest management practices for the study area was developed (Table 26). Land-use factor codes, vegetation factor class, and slope class were then used to assign a particular stem diameter-stem spacing curve to each of the terrain patches as shown in Table 27. The stem diameter and stem spacing values, associated with stem diameter class and stem spacing class, are given in Table 22.

Visibility data

68. Supporting data and reasonable assumptions, based on data from other areas with similar climate, were used to develop a set of visibility descriptions that covered the range of visibility associated with the E-FOSS study area (Table 28). Land use and slope were then used to assign the appropriate visibility code to each terrain patch as shown in Table 29. The factor values associated with each visibility factor class are given in Table 22.

Urban data

69. All urban areas were assigned codes; villages were assigned a code of 1, towns were assigned a code of 2, cities were assigned a code of 3, and all other nonurban areas were assigned a code of 4.

70. The areal terrain predictions module of AMM uses actual values

for the numerous terrain factors rather than class designators. In a final step, numerical values for each factor in a specific patch are assigned random values within each designated class range describing the patch. Thus, two patches that are identical at the factor class interval level are no longer necessarily identical at the factor value level. This final step in assigning terrain factor values to the map is done only once to complete the map legend. When the legend is completed, all vehicles subsequently see each individual patch in terms of an identical array of numerical values for the terrain factors describing it.

71. When the qualitative composite map legend data have been translated and values assigned, the result is a terrain factor complex, or patch, map containing all of the areal terrain data for the mapped area that are needed by AMM (Table 30). Moreover, the map and all of the data are immediately available for making vehicle performance predictions, statistical aggregations of performance in the area, performance maps, etc.

Cover and Concealment Related Data

72. Parameters describing cover and concealment were determined from the topographic and vegetation data prepared for the mobility analysis. Reasonable and consistent values of these parameters were assigned to each terrain patch based on these data and equations developed by Stollmack (1966). General definitions of the nine factors used are given below:

a. Terrain unit number: Number referring to an area described by the same set of factor values.

b. Density of clumps: Number of clumps (clusters) of vegetation per area of terrain.

c. Maximum distance to clump: Maximum distance between center line of target (vehicle) and center line of a vegetation clump behind which the target can remain completely concealed from a certain observation point.

d. Probability of complete trace concealment: Probability that a given target (vehicle), while moving, in each 100-m grid is completely hidden by vegetation clumps from

certain observation points.

e. Clump height: Height of a vegetation clump.

f. Probability of fraction of trace concealed: Probability that a given target (vehicle), while moving, in each 100-m grid is partially concealed during the traverse through the area from certain observation points by vegetation clumps.

g. Terrain complexity: The number of identifiable avenues of approach from which an observer could expect a target to appear.

h. Root-mean-square cover: Microtopographic relief, not shown on 1:50,000 Army Map Service topographic maps, that is capable of hiding all or some portion of the target.

i. Tree height: Height of predominant trees in a terrain unit.

Vehicle Characterization Data

73. Characteristics and performance data for the study vehicles were obtained from the U. S. Army Tank and Automotive Research and Development Command and Aberdeen Proving Ground.

PART IV: SUMMARY AND RECOMMENDATIONS

Summary

74. In this study, terrain and mobility data were developed and structured for input to the CARMONETTE VI and AMSWAG combat models. Data were developed for a six 1:50,000 quadrangle area in the Federal Republic of Germany using a array cell size of 100 by 100 m. The data for each quadrangle area were developed using WES procedures and are stored on magnetic tape at WES and TRASANA.

75. This terrain study responds, in part, to the latest thrust in the Department of Defense (DOD) to use realistic terrain data for the design, development, testing, and evaluation of DOD equipment. Realistic terrain data sets, encompassing the influence of weather conditions, are illustrated in this report. These data sets permit the determination of the relative terrain sensitivity of different pieces of equipment under study in E-FOSS.

76. In light of the above DOD thrust, and with some degree of urgency and concern, it is noted that it is necessary that some of the important data and procedures used in developing terrain data in the E-FOSS quadrangles be updated and/or improved as soon as possible. Of particular concern are the vegetation data and the terrain cover data as discussed in paragraphs 26-28 and 30-38, respectively.

Recommendations

77. Improvements in the vegetation data generated for the E-FOSS quadrangles should be updated using data obtained by WES field teams and data prepared by the Terrain Analysis Center during the V Corps Study (paragraph 28). It is also recommended that for future studies of this type that data on vegetation heights be obtained using recently acquired, larger scaled areal photography and photogrammetric procedures. Modification should also be made to the WES Terrain Shielding Model to allow for more realistic determination of the target cover parameter (paragraph 38).

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Table 1

Basic Content of Terrain Input Data for AMSWAG

Terrain Unit Number
Soil Type (FG, CG, MK, or CH)
Urban Area Code (Village, Town, City, Urban)
Soil Strength (Dry, Average, Wet, Wet/Wet)
Slope Magnitude (%)
Obstacle Approach Angle (deg)
Obstacle Height (in.)
Obstacle Width (in.)
Obstacle Length (ft)
Obstacle Spacing (ft)
Obstacle Spacing Type (Random, Linear)
Surface Roughness, rms* (1/10 in.)
Stem Spacing (ft) for Stems of Diameter >0 in.
Stem Spacing (ft) for Stems of Diameter >1 in.
Stem Spacing (ft) for Stems of Diameter >2.4 in.
Stem Spacing (ft) for Stems of Diameter >3.9 in.
Stem Spacing (ft) for Stems of Diameter >5.5 in.
Stem Spacing (ft) for Stems of Diameter >7.0 in.
Stem Spacing (ft) for Stems of Diameter >8.7 in.
Stem Spacing (ft) for Stems of Diameter >9.8 in.
Visibility Distance for Jan-Mar (ft)
Visibility Distance for Apr-Jun (ft)
Visibility Distance for Jul-Sep (ft)
Visibility Distance for Oct-Dec (ft)
Urban Code

* rms = root-mean-square

Table 2

Basic Content of Cover/Concealment Data* for AMSWAG

Terrain Unit Number
Density of Clumps (No./km^2)
Maximum Distance to Clump (m)
Probability of Complete Trace Concealment
Clump Height (m)
Fraction of Trace Concealed
Terrain Complexity
RMS Cover (m)
Tree Height (m)

* For a general definition of these factors see paragraph 72, and for complete definition see Stollmack (1966).

Table 3

Average Vehicle Speed (mph) on Primary Roads in E-FOSS West Germany Study Area

Vehicle	Speed for Slope* Indicated 0-2%	>2-5%	>5-7%	>7%
		Dry		
M113A1 EXT	31.2	31.2	28.5	28.3
T62	28.0	27.8	25.1	25.0
BMP	31.9	31.9	31.4	31.4
M113A1	34.8	34.6	28.0	27.9
BRDM-2	47.6	38.1	32.9	32.6
XM1	37.7	37.7	34.7	34.7
CMICV	37.3	37.3	31.2	31.1
M60A1	27.3	26.9	24.0	23.9
FT1	31.9	31.9	28.2	27.7
		Wet		
M113A1 EXT	30.1	30.1	27.5	27.4
T62	27.2	27.0	24.4	24.4
BMP	30.8	30.8	30.2	30.2
M113A1	33.3	33.2	27.1	27.0
BRDM-2	37.9	36.3	31.5	31.3
XM1	36.2	36.2	33.2	33.2
CMICV	35.7	35.7	30.0	30.0
M60A1	26.5	26.2	23.4	23.4
FT1	30.8	30.8	27.2	26.8

* Speed is based on a vehicle traveling one third of time upslope, one third downslope, and one third parallel to the indicated slope.

Table 4

Average Vehicle Speed (mph) on Secondary Roads in E-FOSS West Germany Study Area

Vehicle	Speed for Slope* Indicated 0-2%	>2-5%	>5-10%	>10-20%	>20-26.9%	>27%
			Dry			
M113A1 EXT	29.6	29.6	24.0	19.7	13.6	13.5
T62	26.4	26.4	22.8	17.8	13.2	13.1
BMP	30.4	30.4	27.9	22.6	16.1	16.0
M113A1	29.8	29.8	25.3	19.1	14.8	14.7
BRDM-2	31.9	31.9	26.4	21.3	15.6	15.5
XM1	35.5	35.2	30.5	24.9	16.5	16.4
CMICV	33.4	33.4	27.9	21.2	13.3	13.2
M60A1	25.6	25.4	21.3	16.9	12.5	12.4
FT1	30.4	30.4	26.0	21.3	15.3	15.2
			Wet			
M113A1 EXT	28.6	28.6	23.3	19.3	13.2	13.1
T62	25.6	25.6	22.2	17.5	12.8	12.7
BMP	29.4	29.4	26.9	22.0	15.2	15.1
M113A1	28.8	28.8	24.5	18.7	14.3	14.2
BRDM-2	30.3	30.3	25.3	20.6	14.9	14.8
XM1	33.7	33.7	29.2	24.1	15.5	15.4
CMICV	32.1	32.1	27.0	20.7	12.9	12.8
M60A1	24.8	24.8	20.8	16.6	12.0	11.9
FT1	29.4	29.4	25.2	20.7	14.6	14.5

* Speed is based on a vehicle traveling one third of time upslope, one third downslope, and one third parallel to the indicated slope.

Table 5

Average Vehicle Speed (mph) on Trails in E-FOSS West Germany Study Area

Vehicle	Speed for Slope* Indicated									
	0-2%	>2-5%	>5-10%	>10-20%	>21-30%	>31-40%	>41-50%	>51-60%	>61-70%	>70%
					Dry					
M113A1 EXT	14.4	14.0	12.9	12.9	10.1	8.2	6.6	4.9	0.4	0.2
T62	15.9	15.9	13.7	13.6	10.6	9.0	7.3	4.7	0.4	0.2
BMP	15.6	15.5	13.9	13.4	10.3	9.9	9.5	9.0	0.4	0.2
M113A1	13.8	13.7	12.9	12.3	10.7	6.9	5.1	4.2	0.4	0.2
BRDM-2	8.4	8.4	8.2	8.1	6.5	5.8	5.6	3.6	0.4	0.2
XM1	22.9	22.4	18.6	18.5	15.2	13.4	10.9	8.9	0.4	0.2
CMICV	16.9	16.7	15.6	14.1	11.8	10.8	7.8	5.4	0.4	0.2
M60A1	16.1	16.1	14.2	13.1	10.9	8.3	6.0	4.0	0.4	0.2
FT1	18.5	18.0	15.9	15.9	9.5	9.1	8.7	8.0	0.4	0.2
					Wet					
M113A1	14.4	13.9	12.6	12.2	9.6	7.6	0.1	0.1	0.1	0.1
T62	15.5	15.5	13.2	12.8	9.6	7.8	0.1	0.1	0.1	0.1
BMP	15.6	15.4	13.6	13.0	8.9	4.3	0.1	0.1	0.1	0.1
M113A1	13.8	13.7	12.8	12.0	10.2	6.0	0.1	0.1	0.1	0.1
BRDM-2	8.4	8.4	7.9	7.4	0.1	0.1	0.1	0.1	0.1	0.1
XM1	22.9	21.9	17.8	17.3	14.3	11.1	0.1	0.1	0.1	0.1
CMICV	16.9	16.6	15.4	12.9	11.2	9.0	0.1	0.1	0.1	0.1
M60A1	15.9	15.6	13.6	12.2	10.3	7.1	0.1	0.1	0.1	0.1
FT1	18.4	17.6	15.4	14.9	9.2	7.9	0.1	0.1	0.1	0.1

* Speed is based on a vehicle traveling one third of time upslope, one third downslope, and one third parallel to the indicated slope.

Table 6

Vegetation Data* in Federal Republic of Germany

Site Number	1:50,000 Map Sheet Name And Number	Site Location (UTM Coordinates)	Type of Vegetation	Average Tree Height in 1971 m	Estimated Tree Height in 1978 m	Average Stem Diameter in 1971 cm	Average Stem Diameter in 1978 cm	Stem Diameter Range in 1971 cm	Stem Diameter Range in 1978 cm
1	Fulda (L5524)	493053	Fir	25	27	23	24	12-34	12-36
2	Hunfeld (L5324)	574277	Beech	20	22	23	25	9-36	10-38
3	Neukirchen (L5122)	358334	Fir (planted in rows)	20	21	20	22	7-26	8-28

* Data were available for only three of the six E-FOSS quadrangles.

Table 7

Fifty Randomly Selected Target Positions Used To Calculate Cover

Position Number	100-m Grid Location* x-Coordinate	y-Coordinate
1	81	90
2	81	157
3	81	181
4	81	205
5	81	240
6	111	107
7	111	141
8	98	181
9	94	196
10	111	181
11	111	192
12	111	223
13	111	239
14	141	97
15	141	130
16	141	156
17	141	197
18	141	212
19	141	222
20	141	238
21	171	108
22	171	114
23	171	128
24	171	147
25	171	177
26	171	198
27	171	222
28	171	244
29	201	96
30	201	104
31	201	126
32	201	130
33	201	137
34	201	146
35	201	149
36	201	171
37	201	201
38	201	215
39	201	226
40	201	231
41	97	211
42	97	102
43	212	102
44	210	178
45	154	171
46	136	177
47	96	131
48	92	204
49	95	291
50	56	128

* Origin of data array is the upper left corner (i.e. northwest corner) of the elevation grid array. Note that this is different from the origin as required for the CARMONETTE combat model (i.e. the lower left corner).

Table 8

Target Cover Calculations for Grid Position
x=201, y=215, Hunfeld Quadrangle

Target Height cm	Target Cover, in percent, Considering a Weapon Height of 200 cm Above the Ground Surface — Range, m: 500	1000	2000	3000
500	37.5	65.3	91.9	100
450	37.5	65.3	91.9	100
400	41.7	69.4	92.9	100
350	41.7	69.4	92.9	100
300	41.7	69.4*	92.9	100
250	41.7	69.4	92.9	100
200	41.7	71.4	92.9	100
150	50.0	71.4	92.9	100
100	50.0	71.4	94.9	100
50	58.3	73.5	94.9	100

* The target cover value used by WES for the CARMONETTE input data is the value for a height of 300 cm and range of 1000 m.

Table 9

Cross-Country Trafficability Codes for Wet Conditions

Cross-Country Mobility Codes	Speed Limiting Class	Soil Strength Class Range* Wet Condition RCI
1	1	<70
2	1	>70
3	2	≤40
4	2	>40- ≤100
5	2	>100
6	3	≤40
7	3	>40- ≤100
8	3	>100
9	4	≤40
10	4	>40- ≤100
11	4	>100
12	5	≤40
13	5	>40- ≤100
14	5	>100
15	6	<300

* Soil strength for the 0- to 6-in. layer.

Table 10

Soil Strength Values for Wet and Dry Conditions Used to Predict Vehicle Speeds

Trafficability Code	Soil Strength Values, RCI* Dry	Wet
1	180	35
2	300	270
3	180	35
4	270	70
5	300	270
6	180	35
7	270	70
8	300	270
9	180	35
10	270	70
11	300	270
12	180	35
13	270	70
14	300	270
15	300	270

NOTE: A surface roughness value of 0.7 root-mean-square and a recognition distance of 125 ft were used to predict vehicle speed.

* For a 0- to 6-in. layer.

Table 11

Speed Predictions for M113A1 Vehicle

Cross-Country Code	Terrain Slope, percent 0*	+ 5	+10	+15	+20	+25	+30	+35	+40	+45	+50	+55	+60
						Dry Conditions							
1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.5	2.7	2.2	1.9	1.8	1.2
4	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.5	2.8	2.3	1.9	1.8	1.3
5	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.6	2.8	2.3	1.9	1.8	1.3
6	10.4	10.4	10.4	10.4	10.2	7.6	4.7	3.5	2.7	2.2	1.9	1.8	1.2
7	10.4	10.4	10.4	10.4	10.4	7.9	4.9	3.5	2.8	2.3	1.9	1.8	1.3
8	10.4	10.4	10.4	10.4	10.4	7.9	4.9	3.6	2.8	2.3	1.9	1.8	1.3
9	15.2	15.2	15.2	10.7	10.2	7.6	4.7	3.5	2.7	2.2	1.9	1.8	1.2
10	15.2	15.2	15.2	10.7	10.4	7.9	4.9	3.5	2.8	2.3	1.9	1.8	1.3
11	15.2	15.2	15.2	10.7	10.4	7.9	4.9	3.6	2.8	2.3	1.9	1.8	1.3
12	17.8	17.8	17.8	10.7	10.2	7.6	4.7	3.5	2.7	2.2	1.9	1.8	1.2
13	17.8	17.8	17.8	10.7	10.4	7.9	4.9	3.5	2.8	2.3	1.9	1.8	1.3
14	17.8	17.8	17.8	10.7	10.4	7.9	4.9	3.6	2.8	2.3	1.9	1.8	1.3
15	31.2	31.2	19.3	10.7	10.4	7.9	4.9	3.6	2.8	2.3	1.9	1.8	1.3
						Wet Conditions							
1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1
2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
3	4.6	4.6	4.6	4.6	4.6	3.9	3.0	2.4	2.0	1.8	1.3	0.4	0.1
4	4.6	4.6	4.6	4.6	4.6	4.6	4.0	3.0	2.5	2.0	1.8	1.5	0.9
5	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.5	2.8	2.3	1.9	1.8	1.3
6	10.4	10.4	10.4	8.9	5.6	3.9	3.0	2.4	2.0	1.8	1.3	0.4	0.1
7	10.4	10.4	10.4	10.4	9.1	5.6	4.0	3.0	2.5	2.0	1.8	1.5	0.9
8	10.4	10.4	10.4	10.4	10.4	7.9	4.9	3.5	2.8	2.3	1.9	1.8	1.3
9	15.2	11.7	10.5	8.9	5.6	3.9	3.0	2.4	2.0	1.8	1.3	0.4	0.1
10	15.2	15.2	12.1	10.6	9.1	5.6	4.0	3.0	2.5	2.0	1.8	1.5	0.9
11	15.2	15.2	15.2	10.7	10.4	7.9	4.9	3.5	2.8	2.3	1.9	1.8	1.3
12	17.8	11.7	10.5	8.9	5.6	3.9	3.0	2.4	2.0	1.8	1.3	0.4	0.1
13	17.8	17.8	12.1	10.6	9.1	5.6	4.0	3.0	2.5	2.0	1.8	1.5	0.9
14	17.8	17.8	17.8	10.7	10.4	7.9	4.9	3.5	2.8	2.3	1.9	1.8	1.3
15	31.2	31.2	19.3	10.7	10.4	7.9	4.9	3.5	2.8	2.3	1.9	1.8	1.3

* Speeds for zero slope class are considered maximum safe speeds for all downslope classes.

Table 12

Vehicle Characteristics Used in the Army Mobility Model (AMM)

No.	Identification	Dimensions	U. S. Comparison Vehicles: XM1	M60A1	CMICV	M113A1	Foreign Comparison Vehicles: Unnamed	T62	BMP	BRDM
1	Vehicle type (NVEH = 0) for tracked and 1 for wheeled	--	0	0	0	0	0	0	0	1
2	Gross vehicle weight	lbs	115,000.	104,000.	48,000.	24,600.	84,000.	80,000.	29,000.	15,700.
3	Track type (NFL = 0) for flexible and 1 for girderized	NA	0	0	0	0	0	0	0	NA
4	Grouser height for tracks	NA	2	2.	1	1	1	1	2	NA
5	Tire ply rating	--	NA	NA	NA	NA	NA	NA	NA	8
6	Gross rated horsepower	bhp	1,500.	643.	448.	209.	756.	580.	279.	139.
7	Number of tracks or tires	--	2.	2.	2.	2.	2.	2.	2.	4.
8	Number of axles	--	NA	NA	NA	NA	NA	NA	NA	2
9	Vehicle width	in.	141.5	143.0	126.5	105.8	134.0	130.0	116.0	92.5
10	Vehicle length	in.	307.0	273.0	251.6	192.0	268.0	259.0	264.0	227.0
11	Track width or nominal tire width	in.	25.0	28.0	21.0	15.0	22.8	22.8	11.7	13.0
12	Wheel rim diameter on road wheel radius	in.	NA	NA	NA	NA	NA	NA	NA	18.0
13	Recommended tire pressure (cross-country)	psi	NA	NA	NA	NA	NA	NA	NA	17
14	Area of one-track shoe (tracked) or number of wheels (wheeled) (duals as one)	sq in. or #	193.7	194.0	126.0	90.0	125.0	125.4	65.0	4
15	Number of bogies (tracked) or chain indicator wheeled (0 = no chains; 1 = chains)	--	14	12	12	10	12	10	12	0
16	Vehicle ground clearance at the center of greatest wheel span	in.	NA	NA	NA	NA	NA	NA	NA	14.7
17	Minimum vehicle ground clearance	in.	19.0	18.0	17.2	16.0	18.0	16.0	15.7	11.5
18	Rear end clearance (vertical clearance of vehicle's trailing edge)	in.	36.5	40.0	31.0	24.5	20.0	20.0	15.5	25.0
19	Vehicle departure angle	deg	38.0	42.5	77.5	40.0	70.0	59.0	56.0	38.0
20	Vehicle approach angle	deg	58.0	90.0	82.0	70.0	90.0	55.0	28.0	40.0
21	Length of track on ground or wheel diameter	in.	183.5	171.0	152.0	109.0	173.0	164.0	141.0	43.6
22	Height of vehicle pushbar, bumper or leading edge	in.	44.5	45.0	42.0	30.0	35.0	34.0	54.0	54.5
23	Distance between first and last wheel center lines	in.	180.5	167.0	149.0	105.0	170.0	161.0	138.0	122.3
24	Horizontal distance from the center of gravity to the front wheel center lines	in.	87.1	109.0	71.3	52.0	86.0	115.0	78.5	62.3
25	Vertical distance from the center of gravity to the road wheel center lines	in.	36.4	36.0	27.8	24.0	34.0	32.5	26.0	20.5
26	Maximum span between adjacent wheel center lines	in.	NA	NA	NA	NA	NA	NA	NA	44.0
27	Vertical distance from the ground to center of rear wheel (idler or sprocket for tracked vehicle)	in.	35.8	43.0	28.7	20.0	32.8	28.2	25.5	21.2
28	Track thickness plus the radius of the rear idler or sprocket	in.	12.9	18.0	10.5	9.8	11.0	13.0	13.2	NA
29	Road wheel radius plus track thickness	in.	15.6	13.0	14.7	14.5	14.0	18.2	13.5	NA
30	Loaded rolling radius of tire (cross-country tire pressure) or sprocket pitch radius	in.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.2
31	Height of rigid point used to determine approach angle	in.	39.3	45.0	42.0	28.2	35.0	38.0	49.5	24.2
32	Maximum breaking force the vehicle develops	lbs	44,850.	83,200.	28,800.	19,680.	50,400.	48,000.	17,400.	12,560.
33	Loaded wheel deflection (at sand tire pressure)	%	NA	NA	NA	NA	NA	NA	NA	25.
34	Distance vehicle spans before significant motion begins	in.	87.0	67.0	74.5	49.7	86.0	82.0	70.0	62.3
35	Maximum force the pushbar can withstand		230.0	185.0	55.0	55.0	160.0	200.0	70.0	15.0
36	Maximum axle loads/gross vehicle weight	--	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.510
37	Vehicle rated horsepower per ton	hp/ton	26.1	12.4	18.7	17.0	18.0	14.5	19.3	17.8
38	Transmission type (0 = automatic, 1 = manual)	--	0.	0.	0.	0.	1.	1.	1.	1.
39	Final drive gear ratio	--	4.30	5.08	4.40	3.93	6.71	6.71	4.72	6.83
40	Final drive gear efficiency	--	0.98	0.90	0.95	0.95	0.95	0.95	0.97	0.98
41	Number of gear ratios	--	4.	2.	3.	3.	5.	5.	5.	8.
42	Transmission efficiency	--	0.98	0.90	0.95	0.95	0.95	0.95	0.95	0.95

INCL 1

Table 13

Format for Terrain Input Data for AMSWAG Combat Model

Model Input Data Deck 4*

Mobility Terrain Data Legend (Basic Map)

(Cards numbered sequentially with Decks 2, 3)

Mobility terrain data for each patch in basic map area

Card NJ + 1: Alphameric heading identifying data type and basic map area to which data apply

FORMAT (10A6)

Cards (NJ + 2), (2* NTER + NJ + 1): Patch Data (2 cards/patch)

First Card for a patch:

I5	Terrain Unit ID
I2	Soil Type Code (1 = Fine Grained, 2 = Coarse Grained, 3 = Muskeg, 4 = CH)
I2	Urban Area Code (1 = village, 2 = town, 3 = city, 4 = nonurban)
I4	Soil Strength Dry Season (CI or RCI)
I4	Avg Season
I4	Wet Season
I4	W-Wet Season
I4	Slope (%)
I4	Obstacle Approach Angle (deg)
I4	Obstacle Height (in.)
I4	Obstacle Width (in.)
I4	Obstacle Length (ft)
I4	Obstacle Spacing (ft)
I4	Obstacle Spacing Tape (1 = Random, 2 = Linear)
I4	Surface Roughness, rms (1/10 in.)

Second Card for a patch:

I5	Terrain Unit ID
I4	Stem Spacing (ft) for Stems of Diameter > 0 in.
I4	Stem Spacing (ft) for Stems of Diameter > 1 in.
I4	Stem Spacing (ft) for Stems of Diameter > 2.4 in.
I4	Stem Spacing (ft) for Stems of Diameter > 3.9 in.
I4	Stem Spacing (ft) for Stems of Diameter > 5.5 in.
I4	Stem Spacing (ft) for Stems of Diameter > 7.0 in.
I4	Stem Spacing (ft) for Stems of Diameter > 8.7 in.
I4	Stem Spacing (ft) for Stems of Diameter > 9.8 in.
I4	Visibility Distance for Jan-Mar (ft)
I4	Visibility Distance for Apr-Jun (ft)
I4	Visibility Distance for Jul-Sep (ft)
I4	Visibility Distance for Oct-Dec (ft)

* It is noteworthy that the AMSWAG combat model also requires several other data decks in addition to the WES-prepared data decks included in Tables 13-15 for operation of the model. The data deck numbers used here have the correct sequencing numbers as used by the model.

Table 14

Format for Cover and Concealment Input Data for AMSWAG Combat Model

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Model Input Data Decks 5 and 6

DCON/DCOV Terrain Data Legend (Basic Map)

Concealment and cover terrain data for each patch in basic map area

Deck 5: Summer

Deck 6: Winter

Each deck:

Card 1: Alphameric heading identifying basic map area and season

FORMAT (10A6)

Cards 2: (NTER + 1): DCON/DCOV Data

I5	Terrain Unit ID
F8.0	Density of Clumps ($1/km^2$)
F8.0	Max. Dist. to Clump (m)
F8.2	Probability of Complete Trace Concealment
F8.1	Clump Height (m)
F8.2	Fraction of Trace Concealed
I5	Terrain Complexity
F8.2	RMS cover (m)
F8.1	Tree Height (m)

Table 15

Format for Vehicle Characteristics Data for AMSWAG Combat Model

Model Input Data Deck 14

Vehicle Data (one deck for each vehicle)

Vehicle data decks vary with

a. Vehicle Type: KVD Card 2, col 1 = 0 tracked
= 1 wheeled

b. Whether or not power train performance is to be input in the form of a tractive force-speed curve or computed internally from engine transmission and drive train characteristics:

NTTE Card 12, col 1 > 0 compute curve
< 0 curve to be input

c. When NTTE is coded as 0, whether or not the power train incorporates a hydrodynamic torque converter:

TVAR Card 9, col 1 = 0 yes
= 1 no

d. Whether Vehicle Cone Index (VCI) is to be calculated in the model or supplied as an input:

VD1 Card 24, col 1 = 1 compute internally
= 2 supplied as input

(Continued)

Table 15 (Continued)

Deck 14 (Continued)*

Makeup of Vehicle Data Decks:

Vehicle Type	Tracked						Wheeled					
Power Train	C				I		C				I	
Torque Converter	N		Y		NA		N		Y		NA	
VCI	C	I	C	I	C	I	C	I	C	I	C	I
Card(s) 1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1
4T	1	1	1	1	1	-	-	-	-	-	-	-
4W	-	-	-	-	-	1	1	1	1	1	1	1
5T	1	1	1	1	1	1	-	-	-	-	-	-
5W	-	-	-	-	-	-	1	1	1	1	1	1
6T	1	1	1	1	1	1	-	-	-	-	-	-
7	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1
11	M	M	M	M	M	M	M	M	M	M	M	M
12	1	1	1	1	1	1	1	1	1	1	1	1
13P	M	M	M	M	-	-	M	M	M	M	-	-
13T	-	-	-	-	M	M	-	-	-	-	M	M
14P	-	-	1	1	-	-	-	-	1	1	-	-
15P	-	-	M	M	-	-	-	-	M	M	-	-
16P	-	-	1	1	-	-	-	-	1	1	-	-
17P	-	-	M	M	-	-	-	-	M	M	-	-
18	1	1	1	1	1	1	1	1	1	1	1	1
19	M	M	M	M	M	M	M	M	M	M	M	M
20	1	1	1	1	1	1	1	1	1	1	1	1
21	M	M	M	M	M	M	M	M	M	M	M	M
22	1	1	1	1	1	1	1	1	1	1	1	1
23	M	M	M	M	M	M	M	M	M	M	M	M
24	1	1	1	1	1	1	1	1	1	1	1	1
25	-	1	-	1	-	1	-	1	-	1	-	1
26W	-	-	-	-	-	-	1	1	1	1	1	1

(Continued)

* C = Calculate in model, I = input.
N = No; y = yes; NA = not applicable.
M = 1 or more, depending on array length.

Table 15 (Continued)

Deck 14 (Continued)			
Card 1:	FORMAT (12A6) Alphameric heading identifying vehicle		
Card 2:	FORMAT (I7, 9F7.0)		
1	Vehicle Type: Tracked = 0, Wheeled = 1	--	KVD
2	Gross Vehicle Weight	lb	W
Card 3:	FORMAT (10F7.0)		
1	Vehicle length	in.	VL
2	Vehicle width	in.	WV
3	Height of leading edge	in.	HP
4	Height of point determining angle of approach	in.	HB
5	Minimum ground clearance	in.	GCX
6	Horizontal gap vehicle will span without appreciable pitch-in	in.	DS
	FOR TRACKED VEHICLE (KVD = 0)		
7	Distance from vehicle center of gravity to rearmost possible pivot point on track system	in.	GC
	FOR WHEELED VEHICLE (KVD = 1)		
7	Ground clearance between innermost axles	in.	GC
8	Distance from front to rear axle centers	in.	TL
9	Maximum axle-to-axle center distance between adjacent axles	in.	DWX
Card 4T:	(Tracked Vehicle Only) FORMAT (10F7.0)		
1	Angle of approach	deg	AV
2	Angle of line from center of gravity to rear pivot point (Card 3, col 7) with horizontal	deg	ACG
3	Max force leading edge can withstand	lb	FLEW
Card 4W:	(Wheeled Vehicle Only) FORMAT (10F7.0)		
1	Angle of Approach	deg	AV
2	Max force leading edge can without	lb	FLEW
Card 5T:	(Tracked Vehicle Only) FORMAT (10F7.0)		
1	Track-ground contact length	in.	XTL
2	Distance from front to rear road wheel centers	in.	TL
3	Track width	in.	TW
4	Area of single track shoe	sq in.	ATS

(Continued)

Table 15 (Continued)

Deck 14 (Continued)			
5	No. of road wheels in contact with ground-contacting track	--	BN
6	Track grouser height	in.	GH
7	Track type: 0 = flexible, 1 = girderized	--	XGF
8	No. of tracks	--	XNTE
Card 5W:	(Wheeled Vehicle Only)		
1	Tire section width	in.	XTW
2	Tire rim diameter	in.	XRDT
3	Tire outside diameter	in.	XWD
4	Tire rolling radius	in.	RR
5	Tire cross-country inflation pressure	psi	XTP
6	No of wheels on vehicle (dual tires = one wheel)	--	XNT
7	No. of tires on vehicle	--	XNTE
8	Tire ply rating	--	TPR
9	Chains fitted?: 0 = No, 1 = yes	--	XCF
10	No. of axles	--	XNA
Card 6T:	(Tracked Vehicle Only) FORMAT (10F7.0)		
1	Effective road wheel radius, including thickness of track	in.	RWR
2	Effective rear idler or sprocket radius, including thickness of track	in.	RISR
3	Height of rear idler or sprocket above ground	in.	HRIS
4	Distance from center of gravity to center of rear idler or sprocket	in.	DRISCG
Card 6W:	(No corresponding card for Wheeled Vehicle)		
Card 7:	FORMAT (10F7.0)		
1	Max braking force/gross vehicle weight as determined by brake performance	--	XBC
Card 8:	FORMAT (10F7.0)		
1	Horizontal distance from center of gravity to first road wheel or front axle center	in.	TCMCGF
2	Height of center of gravity above road wheel or axle centers	in.	TCMCGH
3	If tracked: Same as Card 6T, col 3	in.	TCMHC
4	If wheeled: Same as Card 5W, col 4		
4 4	Height of trailing edge above ground	in.	TCMREC
5	If tracked: Sprocket pitch radius If wheeled: Same as Card 8T, col 4	in.	TCMRWW
6	Angle of departure	deg	TCMVDA
Card 9:	FORMAT (10F7.0)		
1	Transmission Type: 0 = automatic, 1 = manual	--	TVAR
2	Transmission efficiency	--	EFF
3	Final drive ratio (all reductions downstream of last variable ratio--in transmission, transfer case or axle input--to driving sprockets or wheels)	--	FDR

(Continued)

Table 15 (Continued)

Deck 14 (Continued)

4	Final driver efficiency	--	FDREF
5	Horsepower per ton	HP/T	HPT
6	For tracked vehicle only: same as Card 8, col 5	in	TEMP

Card 10: FORMAT (I7, 9F7.0)

1	No. of ratios available in transmission system ≤ 18*	--	NG

Card(s) 11: FORMAT (10F7.0)

1, NG	Gear ratios in descending order	--	CR(I)

Card 12: FORMAT (I7, 9F7.0)

1	No. of rpm-torque pairs specified to define engine torque curve, ≤ 30*	--	NTTE
	--or--		
1	If negative, absolute value is number of vehicle speed-tractive force pairs specified to define tractive force-speed curve, ≤ 180*	--	NTTE

Card(s) 13P: (Tractive Force-Speed Curve to be Computed--NTTE >0) FORMAT 10F7.0)

1,3,5,7,9	Engine rpm in ascending order from min to max	rpm	TTE(I,1)
2,4,6,8,10	Engine torque corresponding to rpm in preceding column	lb-ft	TTE(I,2)

Card(s) 13T: (Tractive Force-Speed Curve Supplies as Input--NTTE <0) FORMAT (10F7.0)

1,3,5,7,9	Vehicle speed in ascending order from 0 to V_{max}	mph	FORCE(2,I)
2,4,6,8,10	Tractive force corresponding to speed in preceding column	lb	FORCE(1,I)

NOTE: last point must be (V_{max}, 0)**

Cards 14P thru 17P inclusive are required only

If tractive force-speed curve is not input

and

If transmission incorporates a hydrodynamic torque converter (TVAR = 0)

(Continued)

* Current program dimensions.

** V_{max} = maximum vehicle speed.

Deck 14 (Continued)

Card 14P:	FORMAT (F7.0, I7, 2F7.0)		
1	Torque input for which converter characteristics are given	lb-ft	TC
2	No. of speed ratio-input rpm pairs specified to define converter speed curve, ≤ 30*	--	NTNE1
3	Gear ratio between engine and converter (= 1 if engine and converter are direct-coupled)	--	NTNE1
4	Does converter incorporate lock-up clutch? (0 = No, 1 = yes)	--	LOKUP
Card(s) 15P:	FORMAT (10F7.0)		
1,3,5,7,9	Converter output-to-input speed ratio, in ascending order from 0 to 1	--	TNE1(1,I)
2,4,6,8,10	Input rpm corresponding to speed ratio in preceding column	rpm	TNE1(2,I)
Card 16P:	FORMAT (I7, 9F7.0)		
1	No. of converter speed-ratio torque ratio pairs specified to define converter torque output curve, ≤ 30*	--	NTTM
Card(s) 17P:	FORMAT (10F7.0)		
1,3,5,7,9	Converter output-to-input speed ratio in ascending order from 0 to 1	--	TTM(1,I)
2,4,6,8,10	Torque output-to-input ratio corresponding to speed ratio in preceding column	--	TTM(2,I)
All vehicles require cards 18 thru 24, inclusive			
Card 18:	FORMAT (I7, 9F7.0)		
1	No. of obstacle height, 2.5-g speed limits specified to define obstacle speed limit curve, ≤ 30	--	NSPEED
Card(s) 19:	FORMAT (10F7.0)		
1,3,5,7,9	Obstacle heights in ascending order from zero height to 50 in.	in.	SPEED(1,I)
2,4,6,8,10	2.5-g speed limit over obstacle of height given in preceding column	mph	SPEED(2,I)

(Continued)

* Current program dimensions.

Table 15 (Concluded)

Deck 14 (Concluded)

Card 20: FORMAT (I7, F7.0)

1	No. of roughness-speed limit pairs specified to define ride speed limit curve in cross-country terrain, ≤30*	--	NROUGH

Card(s) 21: FORMAT (10F7.0)

1,3,5,7,9	Terrain microroughness values in accending order from 0 to 8 in. rms	in.	*ROUGH(1,I)*
2,4,6,8,10	Ride speed limit (usually at 6 watts vertical absorbed power at the driver's seat) over cross country terrain of microroughness given in preceding column	mph	ROUGH(2,I)

Card 22 and Card(s) 23 are the same as Card 20 and Cards 21, respectively, except that ride speed limits relate to operations on trails and roads. These data will not be consulted at this time by DYMOB so that dummy cards only are required in the input deck

Card 24: FORMAT (I7, 9F7.0)

1	Flag to signify that vehicle cone index (VCI) will be input rather than calculated by DYMOB routines. This is necessary when all axles or tracks on a vehicle or combination are not powered; i.e. external computations are required for these cases		
	1 = model make computations	--	VD1
	2 = VCI's to be given below	--	VD1

Card 25V: (only if VDI = 2)
FORMAT (10F7.0)

1	VCI_1 in fine-grained soil	--	$FVCI_1$
2	VCI_1 in coarse-grained soil	--	$CVCI_1$
3	Total weight on powered axles and track elements	lb	GVW2

Card 26W: (Wheeled Vehicle only)
FORMAT (10F7.0)

1	Tire rolling radius at sand inflation pressure	--	V_1
2	Tire inflation pressure for operations in sand	psi	V_2
3	Multiplier for tractive force-speed curve resulting from change in rolling radius	--	V_3

* Current program dimensions.

Table 16

Codes for Terrain Factor Maps

Land Use (XYZ)

X	Y		Z*
1. Urban	1	Village	0
	2	Town	0
	3	City	0
	4	Nonurban	0
2. State Forest	1	Deciduous	0-9
	2	Coniferous	0-9
	3	Mixed	0-9
3. Nonstate Forest	1	Deciduous	0-9
	2	Coniferous	0-9
	3	Mixed	0-9
4. Meadows, Pastures	0	Clear	0-9
	1	With Trees	0-9
5. Croplands	0		0-9
6. Other Agriculture	1	Nursery	0-9
	2	Orchard	0-9
	3	Vineyard	0-9
	4	Hop Garden	0-9
7. Other	1	Swamp, Bog	0-9
	2	Peat Cutting	0
	3	Lake	0
	4	Reed Area	0-9
	5	Heath, Bent	0-9
	6	Undermined	0
	7	Rock	0
	8	Sand	0-9
	9	Quarry, Pit	0
8. Out of Bounds	0		0

Z*

0 = Clear
1 = With Trees, Shrubs
2 = Swampy
3 = With Drainage Ditches
4 = With Dry Ditches
5 = With Walls
6 = With Hedges
7 = With Banks
8 = With Banks and Hedges
9 = Controlled Planting - Reforested

Slope (X)

Class (X)	Range %
1	0-2
2	3-5
3	6-10
4	11-20
5	21-40
6	41-60
7	61-70
8	>70

Soil Type (X)

Class (X)	USCS Soil Class*
1	Sand
2	SC, SM
3	MH
4	CH
5	CL
6	Peat (15-45 cm deep)
7	GW, GP, GM
8	Peat (45-100 cm deep)
9	Peat (>100 cm deep)

* USCS = Unified Soil Classification System.

Vegetation (XY)

Description (X)		Height, m (Y)	
1	Coniferous	1	0-2
2	Deciduous	2	3-12
3	Mixed	3	13-25
4	Swamp	4	>25
5	Cultivated		
6	Orchard		
7	Shrubbery		

Surface Geology (XY)

Surface Composition (X)	Description (Y)
1. Gravel, Sand	Plains (Flat), Slope <3%, Relief <10 m
2. Gravel, Sand, Silt, Clay Mixtures	Plains (Undulating), Slope 3 to 8%, Relief 10-20 m
3. Silt (Loess)	
4. Silt and Clay	
5. Peat	
6. Shale, Marl, and Slate	
7. Shale, Interbedded Sandstone, Limestone	
8. Sandstone	
9. Limestone	

Table 17

Example Legends for Terrain Unit Map

Terrain Unit	Land Use Class*	Slope Class*	Soil Type Class*	Vegetation Class*	Surface Geology Class*
105	213	2	5	02,01,23	42
120	217	2	3	02,01,13	42
330	500	1	5	05	41
333	500	2	5	05	41
401	217	3	5	02,01,23	41
402	213	2	5	01,01,22	41
403	213	4	2	01,05,12	22
500	217	3	2	01,05,12	22
501	120*	--	--	--	--
507	500	1	4	05	41
621	500	2	4	05	41

NOTE: When urban, other factors not included.
* See Table 16.

Table 18

Soil Type Class Translation to AMM Soil Type

Soil Type Class	AMM Soil Type	AMM Soil Description
1	2	Sand
2	1	Fine grained
3	1	Fine grained
4	4	Fine grained-slippery
5	1	Fine grained
6	1	Fine grained
7	1	Fine grained
8	1	Fine grained
9	1	Fine grained

Table 19

Soil Type Class Translation to Soil Group Number Required for Soil Moisture Prediction Model

Soil Type Class*	Soil Group Number**
1	0505
2	0606, 0707
3	0808, 0909
4	1010, 1111
5	1010, 1111
6	1414
7	0303, 0707, 1111
8	1414
9	1414

* From Table 16.
** From Table 20.

Table 20

Surface Composition Groups Considered in SMSP

Material			Organic Content %	Drainage* Potential Class	Group Code
Groups with Similar Material in 0- to 15- and 15- to 30-cm Layers					
Water			0	0	8888
Pavement and structures >25% coverage				2	0101
Rock, stones, boulders, and cobbles, P.D. sizes ≥0.074mm is ≥50% and >76.2mm is >25%				2	0202
Coarse-grained P.D. sizes ≥0.074mm is ≥50%	Gravel, P.D. sizes ≥4.76-76.2mm, is >25%	Clean gravel, P.D. sizes <0.074mm is <5%	>0-7	2	0303
		Gravel with fines, P.D. sizes <0.074mm is ≥5-50%		2	0707 or 1111**
	Sand, P.D. sizes ≥0.074-4.76mm, is >25%	Clean sand, P.D. sizes <0.074mm is <5%		2	0505
		Sand with fines, P.D. sizes <0.074mm is ≥5-50%		1	0606
				2	0707
Fine-grained, sizes<0.074mm is >50%	Silt, LL ≤35 and PI ≤15			1	0808
				2	0909
	Clay, LL >35 or PI >15			1	1010
				2	1111
Organic silts and clays (plastic)			>7-30	0	1212
				1	1313
Peat (nonplastic)			>30	0	1414
Groups with Different Material in 0- to 15- and 15- to 30-cm Layers					
Sand, 0-15 cm, over Clay, 15-30 cm			>0-7	1	0610
				2	0711
Silt, 0-15 cm, over Clay, 15-30 cm				2	0911

NOTE: PD = Particle diameter
LL = Liquid limit
PI = Plasticity index

* Drainage potential classified by occurrence of water table as follows:

Class 0 Water table occurs at surface 90% or more of the time

Class 1 Water table occurs at the surface less than 90% and above 120-cm depth 10% or more of the time

Class 2 Water table occurs above 120-cm depth less than 10% of the time

** Gravel with sand matrix coded 0707; gravel with clay matrix coded 1111

Table 21

Soil Water, Density, and Strength Surface Composition Groups with Constant Values Considered in SMSP

Material	Group Code	Water Content* percent	Density** g/cm^3	Strength CI
Water	8888	100	1.00	0 (liquid)
Pavements and structures	0101	1	2.50	750†
Rock, stone, cobbles, boulders	0202	1 to 5	2.15	750†
Clean gravel	0303	1	2.00	100
Saturated organic silt-clay	1212	90†	0.80	25
Peat and muck	1414	90†	0.80	25

* Percent on dry-weight basis except for water.

** Dry density except for water.

† Represents an average value estimated from a small number of samples. Water contents are highly variable and increase with an increase in the percent organic matter of the material.

Table 22

Areal Terrain Factors, Classes and Intervals

Terrain Factors	Class Numbers 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Surface type	Fine-Grained (Other)	Coarse-Grained	Muskeg	CH										
Surface strength (CL or RCI); Class range value selected for prediction	281-300	221-280	161-220	101-160	61-100	41-60	33-40	26-32	17-25	11-16	4-10			
Slope; Class range value selected for prediction	0-<2	2-<5	5-<10	10-<20	20-<40	40-<60	60-≤70	>70						
Obstacle approach angle, deg; Class range value selected for prediction	179	181	176-178	182-184	171-175	185-190	159-170	191-202	149-158	202-211	136-149	212-225	90-135	226-270
Obstacle vertical magnitude, in.; Class range value selected for prediction	3-6	7-10	11-14	15-18	19-24	25-33	33-45							
Obstacle base width, in.; Class range value selected for prediction	48-150	36-47	24-35	12-24	6-12									
Obstacle length, ft; Class range value selected for prediction	1	2-3	4-6	7-10	11-20	21-40	41-100							
Obstacle spacing, ft; Class range value selected for prediction	198	66-197	37-65	26-36	19-25	13-18	9-12	2-8						
Obstacle spacing type	Random	Linear												
Surface roughness x 10; Class range value selected for prediction	1	2-4	5-6	7-8	9-12	13-16	17-22	23-32	33-45					
Stem diameter, in.; Factor value	0	>1	>2.4	>3.9	>5.5	>7.0	>8.7	>9.8						
Stem spacing, ft; Class range value selected for prediction	328	66	51	31	22	16	11	4						
Visibility, ft; Class range value selected for prediction	165-300	79-164	31-78	30-38	20-29	16-19	10-15	6-9	1-5					

Table 23

Obstacle Data in Terms of Obstacle Factor Classes

Obstacle Code	Obstacle Description	Obstacle Factor Class Description					
		Approach Angle	Magnitude	Width	Length	Spacing	Spacing Type
1	No obstacle	1	1	1	1	1	1
2	Stumps	13	2	4	1	3-7	1
3		13	3	4	2	3-7	1
4		13	4	4	2	3-7	1
5		13	5	4	2	3-7	1
6		13	2	4	1	2-3	1
7		13	3	4	2	2-3	1
8		13	5	4	2	2-3	1
9	Logs	13	2	4	3-5	3-5	1
10		13	2	4	3-5	3-5	1
11		13	4	4	3-5	3-5	1
12		13	5	4	3-5	3-5	1
13		13	6	5	3-5	3-5	1
14		13	2	4	3-5	3-5	1
15		13	3	4	3-5	1-4	1
16		13	4	4	3-5	1-4	1
17		13	5	4	3-5	1-4	1
18		13	6	5	3-5	1-4	1
19	Row crops	9 or 11	1	3	7	8	2
20		9 or 11	2	3	7	8	2
21		9 or 11	3	3	7	8	2
22	Broadcast crops	6, 8, 10	1	1-4	7	1-2	2
23		6, 8, 10	2	1-4	7	1-2	2
24		6, 8, 10	3	1-4	7	1-2	2
25	Walls	13	3-5	1-3	7	1-2	2
26	Ledges	13	5-7	1-3	7	1-2	2
27	Hedges and terraces	11 or 13	3-5	1-3	7	1-2	2
28	Boulders	11 or 13	2-5	3	2	7-8	1
29		11 or 13	5-7	2	2	7-8	1
30		11 or 13	2-5	3	2	5-6	1
31		11 or 13	5-7	2	2	5-6	1
32		11 or 13	2-5	3	2	3-4	1
33		11 or 13	5-7	2	2	3-4	1
34		11 or 13	2-5	3	2	1-2	1
35		11 or 13	5-7	2	2	1-2	1
36	Ditches	8 or 11	2-5	1-1	7	1-4	2
37		8 or 10	5-7	1-2	7	1-4	2
38		8 or 10	2-5	1-2	7	4-6	2
39		8 or 10	5-7	1-2	7	4-6	2
40		8 or 10	2-5	1-2	5-7	1-4	1
41		8 or 10	5-7	1-2	3-5	1-4	1
42		8 or 10	2-5	1-2	5-7	3-4	1
43		8 or 10	5-7	1-2	3-5	3-4	1
44		12 or 14	2-5	1-2	7	1-4	2
45		12 or 14	5-7	1-2	7	1-4	2
46		12 or 14	2-5	1-2	7	4-6	2
47		12 or 14	5-7	1-2	7	4-6	2
48		12 or 14	2-5	1-2	5-7	1-4	1
49		12 or 14	5-7	1-2	3-5	1-4	1
50		12 or 14	2-5	1-2	5-7	3-4	1
51		12 or 14	5-7	1-2	3-5	3-4	1
52	Ricefield or other type dikes	11 or 8	3-4	1-2	7	1-2	2
53		11 or 13	3-4	1-2	7	3-4	2
54		11 or 13	5	1-2	7	1	2
55		11 or 13	6	1-2	7	1	2
56		11 or 13	1-2	1-2	7	1-2	2
57	Sand dunes	9	4	1	7	2-3	2
58		11	8-9	7	9	1	1

Table 24

Distribution of Obstacle Codes Based on Land Use and Slope

	Slope	Assigned Obstacle Parameters													
Land-Use Code	Class	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%
210, 220, 230	1-3	1	16	2	14	14	14	22	28	23	28				
	4-8	1	16	2	12	9	12	23	24	24	24	49	12		
211, 221, 231	1-3	1	16	2	14	14	14	22	28	23	28				
	4-8	1	16	2	12	9	12	23	24	24	24	49	12		
213, 223, 233	1-3	1	16	2	14	14	14	22	14	23	14	44	14	49	14
214, 224, 234	4-8	1	16	2	14	9	14	23	14	24	14	45	14	50	14
215, 225, 235	1-8	25	34	26	33	27	33								
216, 226, 236 217, 227, 237	1-8	27	20	37	20	39	20	50	20	44	20				
310, 320, 330	1-3	1	14	2	12	3	12	14	12	22	24	23	24		
	4-8	1	12	2	11	3	11	9	11	23	22	24	22	49	11
311, 321, 331	1-3	1	14	2	12	3	12	14	12	22	24	23	24		
	4-8	1	12	2	11	3	11	9	11	23	22	24	22	49	11
313, 323, 333	1-3	1	16	2	14	3	14	22	14	23	14	44	14	49	14
314, 324, 334	4-8	1	16	2	14	3	14	22	14	23	14	45	14	50	14
315, 325, 335	1-8	25	34	26	33	27	33								
316, 326, 336 317, 327, 337	1-8	27	20	37	20	39	20	50	20	44	20				
400, 401	1-3	22	40	23	40	24	20								
	4-8	22	34	23	33	24	33								
402	1-8	22	20	23	40	24	20								
403	1-3	23	40	24	40	45	20								
	4-8	23	34	24	33	40	33								
404-409	1-3	25	50	26	50										
	4-8	25	34	26	33	27	33								
500-501	1-3	22	40	23	30	24	20	19	10						
503	1-3	23	40	24	40	19	20								
507, 502, 504 505, 508, 509	1-8	23	20	24	20	25	20	26	20	27	20				
610	1-8	19	34	20	33	21	33								
613	1-8	19	25	20	25	21	25	40	25						
620, 621	1-8	22	34	23	33	24	33								
623	1-8	22	25	23	25	24	25	40	25						
625, 622, 624 626, 628, 629	1-8	25	34	26	33	27	33								
627	1-8	25	25	26	25	27	25	36	25						
630-649	1-8	19	34	20	33	21	33								
710	1-8	2	50	9	50										
712	1-8	2	25	3	25	6	25	7	25						
713, 711, 714 715, 716, 717 718, 719	1-8	2	34	9	33	40	33								
720-729	1-8	40	34	41	33	42	33								
730-739	1-8	1	100												
740-752	1-8	1	34	22	33	23	33								
753	1-8	22	34	23	33	40	33								
755-757	1-8	1	20	22	20	25	20	26	20	27	20				
759, 754, 756 758	1-8	1	50	22	50										
760-769	1-8	1	34	22	33	23	33								
770-779	1-8	1	50	28	50										
780-789	1-8	1	34	22	33	23	33								
790, 799	1-8	23	20	40	20	40	20	41	20	42	20	43	20		

Table 25

Distribution of Surface Roughness Classes Based on Land Use, Slope, Surface Geology, and Soils

Lane-Use Code	Slope Class	Assigned Surface Roughness Parameters Class	%	Class	%	Class	%	Class	%	Class	%	Class	%	Class	%
210, 220, 230	1-3	2	20	3	20	4	20	5	20	6	20				
	4-8	3	20	4	16	5	16	6	16	7	16	8	16		
211, 221, 231	1-3	2	20	3	20	4	20	5	20	6	20				
	4-8	3	16	4	14	5	14	6	14	7	14	8	14	9	14
213, 223, 233, 214	1-3	2	20	3	20	4	20	5	20	6	20				
224, 234	4-8	4	20	5	16	6	16	7	16	8	16	9	16		
215, 225, 235	1-8	4	20	5	16	6	16	7	16	8	16	9	16		
216, 226, 236, 217 227, 237	1-8	4	20	5	16	6	16	7	16	8	16	9	16		
310, 320, 330	1-3	2	20	3	20	4	20	5	20	6	20				
	4-8	3	20	4	16	5	16	6	16	7	16	8	16		
311, 321, 331	1-3	2	20	3	20	4	20	5	20	6	20				
	4-8	3	16	4	14	5	14	6	14	7	14	8	14	9	14
313, 323, 333, 314	1-3	2	20	3	20	4	20	5	20	6	20				
324, 334	4-8	4	20	5	16	6	16	7	16	8	16	9	16		
315, 325, 335	1-8	4	20	5	16	6	16	7	16	8	16	9	16		
316, 326, 336, 317 327, 337	1-8	4	20	5	16	6	16	7	16	8	16	9	16		
400, 401, 403	1-3	2	23	3	22	4	22	5	11	6	11	7	11		
	4-8	3	16	4	12	5	24	6	24	7	12	8	12		
402	1-8	2	25	3	25	4	25	5	25						
407, 408	1-3	3	25	4	25	5	25	6	25						
	4-8	3	20	4	16	5	16	6	16	7	16	8	16		
500, 501, 503, 507	1-3	2	25	3	25	4	25	5	25						
	4-8	3	20	4	20	5	20	6	20	7	20				
610, 613	1-3	4	20	5	20	6	20	7	20	8	20				
	4-8	4	20	5	16	6	16	7	16	8	16	9	16		
620, 621	1-3	2	50	3	50										
	4-8	3	25	4	25	5	25	6	25						
623	1-3	3	20	4	20	5	20	6	20	7	20				
	4-8	4	20	5	20	6	20	7	20	8	20				
625	1-3	4	20	5	20	6	20	7	20	8	20				
	4-8	3	25	4	25	5	25	6	25						

(Continued)

NOTE: When soil type class is 6, 7, 8, or 9 or surface geology is 52, 62, 72, 82, or 92, surface roughness of the lowest class is deleted and percentages of this class are equally distributed into the remaining surface roughness classes.

Table 25 (Concluded)

Lane-Use Code	Slope Class	Assigned Surface Roughness Parameters													
		Class	%	Class	%	Class	%	Class	%	Class	%	Class	%	Class	%
627	1-3	3	25	4	25	5	25	6	25						
	4-8	3	25	4	25	5	25	6	25						
629, 622, 624, 626	1-3	3	25	4	25	5	25	6	25						
628	4-8	3	20	4	20	5	20	6	20	7	20				
630-649	1-3	5	34	6	33	7	33								
	4-8	5	34	6	33	7	33								
710, 712	1-8	3	34	4	33	5	33								
713, 711, 714, 715 716, 717, 718, 719	1-8	3	34	4	33	5	33								
720-729	1-8	5	34	6	33	7	33								
730-739	1-8	1	100												
740-752	1-8	3	25	4	25	5	25	6	25						
753, 755, 757	1-8	3	20	4	20	5	20	6	20	7	20				
759, 754, 756, 758	1-8	3	25	4	25	5	25	6	25						
760-769	1-8	5	20	6	20	7	20	8	20	9	20				
770-779	1-8	5	25	6	25	7	25	8	25						
780-789	1-8	3	25	4	25	5	25	6	25						
790-799	1-8	5	25	6	25	7	25	8	25						

Table 26

Vegetation Data in Terms of Stem Diameter - Spacing Classes

Vegetation Code	Vegetation Description	Vegetation Factor Stem Spacing for for Stem Diameter Class >							
		1	2	3	4	5	6	7	8
1	No vegetation	1	1	1	1	1	1	1	1
2	Very large stem diameter (> 10 in.), very dense	8	8	8	8	8	8	8	8
3		7	7	7	7	7	7	7	7
4	Very large stem diameter (> 10 in.), dense	6	6	6	6	6	6	6	6
5		5	5	5	5	5	5	5	5
6	Very large stem diameter (> 10 in.), sparse	4	4	4	4	4	4	4	4
7		3	3	3	3	3	3	3	3
8		2	2	2	2	2	2	2	2
9	Large stem diameter (> 7 in.), very dense	8	8	8	8	8	8	1-7	1-7
10		7	7	7	7	7	7	1-6	1-6
11	Large stem diameter (> 7 in.), dense	6	6	6	6	6	6	1-5	1-5
12		5	5	5	5	5	5	1-4	1-4
13	Large stem diameter (> 7 in.), sparse	4	4	4	4	4	4	1-3	1-3
14		3	3	3	3	3	3	1-2	1-2
15		2	2	2	2	2	2	1	1
16	Medium stem diameter (> 4 in.), very dense	8	8	8	8	1-7	1-7	1	1
17		7	7	7	7	1-6	1-6	1	1
18	Medium stem diameter (> 4 in.), dense	6	6	6	6	1-5	1-5	1	1
19		5	5	5	5	1-4	1-4	1	1
20	Medium stem diameter, sparse	4	4	4	4	1-3	1-3	1	1
21		3	3	3	3	1-2	1-2	1	1
22		2	2	2	2	1	1	1	1
23	Small stem diameter (> 1 in.), very dense	8	8	1-7	1-7	1	1	1	1
24		7	7	1-6	1-6	1	1	1	1
25	Small stem diameter (> 1 in.), dense	6	6	1-5	1	1	1	1	1
26		5	5	1-4	1-4	1	1	1	1
27	Small stem diameter (> 1 in.), sparse	4	4	1-3	1-3	1	1	1	1
28		3	3	1-2	1-2	1	1	1	1
29		2	2	1	1	1	1	1	1
30	Very small stem diamter (> 1 in.), very dense	8	1-7	1	1	1	1	1	1
31		7	1-6	1	1	1	1	1	1
32	Very small stem diameter (> 1 in.), dense	6	1-5	1	1	1	1	1	1
33		5	1-4	1	1	1	1	1	1
34	Very small stem diameter, sparse	3	1-3	1	1	1	1	1	1
35		2	1	1	1	1	1	1	1
36	Mixed stem diameter distribution (very dense small diameters to sparse large diameters)	1-8	2-7	2-6	2-5	2-4	2-3	2-2	1
37	Mixed stem diameter distribution (dense small diameters to sparse medium diameters)	1-6	1-5	1-4	1-3	1-2	1	1	1
38	Mixed stem diameter distribution (sparse small diameters to sparse medium diameters)	1-4	1-3	1-2	1	1	1	1	1
39	Pine-lands	4-6	4-6	4-6	4-6	4-5	4-5	3-4	2-3
40	Spruce - Fir	5-6	5-6	5-6	5-6	5-6	5-6	3-4	2-3
41	Mixed coniferous	7-8	6-7	5-6	5-6	4-5	4-5	3-4	3-4
42	Deciduous	3-5	3-5	3-5	3-5	3-5	3-5	3-4	2-3
43	Mixed **deciduous**	4-6	3-6	3-6	3-5	3-5	3-5	3-4	3-4
44	Mixed coniferous and deciduous	7-8	6-7	5-6	4-5	4-5	4-5	4-5	4-5
45	Mixed coniferous and deciduous	6-8	5-8	5-6	4-5	4-5	3-5	2-3	2-3
46	Temperate climate	7	7	6	4	4	4	4	4
47		7	7	7	7	5-6	5	4	4
48		7	7	7	7	6	6	5	4
49	Temperate climate	8	8	8	7	7	6	5	5
50		8	8	8	8	7	7	6	5
51	Arid	7	7	5-6	4	4	3	3	3
52		2	2	2	2	2	2	2	1

Table 27

Distribution of Vegetation Codes Based on Land Use, Vegetation, and Slope

	Slope	Vegetation	Assigned Vegetation Parameters																	
Land-Use Code	Class	Class	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%
2XX, 3XX	1-8	1, 1, 17	41	52	12	32	31	16												
2XX, 3XX	1-8	2, 1, 23	42	52	17	16	18	16	23	16										
2XX, 3XX	1-8	3, 1, 14	44	52	6	16	5	16	30	16										
2XX, 3XX	1-8	3, 1, 18	44	52	18	16	17	16	24	16										
2XX, 3XX	1-8	3, 1, 7	44	52	6	16	7	16	30	16										
2XX, 3XX	1-8	3, 1, 13	44	52	4	16	5	16	31	16										
2XX, 3XX	1-8	2, 1, 30	43	52	45	32	23	16												
2XX, 3XX	1-8	1, 1, 22	41	52	18	16	17	16	31	16										
2XX, 3XX	1-8	3, 1, 28	44	52	4	16	5	16	23	16										
2XX, 3XX	1-8	3, 1, 29	44	52	5	16	6	16	24	16										
2XX, 3XX	1-8	3, 1, 16	44	52	45	16	5	16	24	16										
2XX, 3XX	1-8	3, 1, 21	44	52	19	32	30	16												
2XX, 3XX	1-8	1, 5, 7	39	52	4	16	5	16	23	16										
2XX, 3XX	1-8	3, 5, 3	41	52	5	16	6	16	24	16										
2XX, 3XX	1-8	3, 5, 8	44	52	6	16	7	16	30	16										
2XX, 3XX	1-8	3, 3, 26	41	52	45	32	31	16												
2XX, 3XX	1-8	1, 5, 5	40	52	45	32	23	16												
2XX, 3XX	1-8	1, 5, 12	39	52	4	32	24	16												
2XX, 3XX	1-8	3, 5, 6	44	52	5	16	6	16	30	16										
2XX, 3XX	1-8	1, 1, 23	42	52	16	16	17	16	31	16										
2XX, 3XX	1-8	1, 5, 2	39	52	6	16	7	16	23	16										
2XX, 3XX	1-8	1, 5, 4	39	52	17	16	16	16	24	16										
2XX, 3XX	1-8	1, 3, 25	39	52	4	16	5	16	30	16										
2XX, 3XX	1-8	3, 5, 1	39	52	5	16	6	16	31	16										
2XX, 3XX	1-8	3, 3, 28	41	52	11	16	12	16	23	16										
2XX, 3XX	1-8	3, 4, 22	45	52	6	16	7	16	24	16										
2XX, 3XX	1-8	3, 1, 25	44	52	11	16	12	16	30	16										
2XX, 3XX	1-8	1, 1, 22	41	52	18	16	17	16	31	16										
2XX, 3XX	1-8	3, 1, 19	44	52	4	16	5	16	31	16										
2XX, 3XX	1-8	3, 1, 20	44	52	19	16	20	16	23	16										
2XX, 3XX	1-8	3, 1, 24	44	52	45	32	24	16												
2XX, 3XX	1-8	3, 1, 25	44	52	12	16	13	16	30	16										
2XX, 3XX	1-8	3, 1, 26	44	52	16	16	17	16	30	16										
2XX, 3XX	1-8	3, 1, 8	44	52	5	16	6	16	31	16										
2XX, 3XX	1-8	3, 1, 9	42	52	6	16	7	16	30	16										
2XX, 3XX	1-8	3, 1, 15	44	52	4	16	5	16	24	16										
2XX, 3XX	1-8	3, 4, 28	41	52	45	32	30	16												
2XX, 3XX	1-8	1, 3, 28	41	52	45	32	31	16												
2XX, 3XX	1-8	1, 3, 23	41	52	11	16	12	16	23	16										
2XX, 3XX	1-8	3, 3, 22	44	52	45	32	24	16												
2XX, 3XX	1-8	3, 3, 24	41	52	5	16	6	16	30	16										
2XX, 3XX	1-8	1, 3, 18	41	52	45	32	31	16												

(Continued)

Table 27 (Concluded)

Land-Use Code	Slope Class	Vegetation Class	Assigned Vegetation Parameters Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%
21X, 31X	1-8	5	42	100																
22X, 32X	1-8	5	39	34	40	33	41	33												
23X, 33X	1-8	5	41	50	44	50														
400	1-8	NA*	1	100																
401	1-8		15	20	15	20	35	20	8	20	8	20								
402	1-8		1	25	15	25	35	28	8	25										
403-409	1-8		1	100																
500	1-8		1	100																
501	1-3		15	50	8	50														
	4-8		15	34	8	33	35	33												
503-509	1-8		1	100																
610, 613	1-8		30	20	31	20	1	20	32	20	33	20								
620	1-3		25	12	6	11	7	11	8	11	18	11	19	11	16	11	4	11	5	11
	4-8		25	16	6	12	7	12	8	12	18	12	19	12	16	12	45	12		
621, 623, 625	1-8		25	16	6	12	7	12	8	12	18	12	19	12	16	12	45	12		
627	1-3		25	16	6	12	7	12	8	12	18	12	19	12	16	12	45	12		
	4-8		27	34	28	33	29	33												
629, 622, 624	1-3		27	34	28	33	29	33												
626, 628	4-8		25	16	6	12	7	12	8	12	18	12	19	12	16	12	45	12		
630-649	1-8		30	25	31	25	32	25	33	25										
710	1-8		20	20	18	16	4	16	5	16	6	16	7	16						
712	1-8		20	16	18	14	2	14	4	14	5	14	6	14	7	14				
713, 711, 714 715, 716, 717, 718, 719	1-8		20	20	18	16	4	16	5	16	6	16	7	16						
720	1-8		6	50	7	50														
721-729	1-8		6	25	7	25	4	25	5	25										
730-739	1-8		1	100																
740-749	1-3		1	100																
	4-8		1	20	15	20	35	20	28	20	29	20								
750	1-8		1	100																
751-753	1-8		1	34	15	33	35	33												
754-759	1-8		1	100																
760-769	1-8		1	25	7	25	8	25	29	25										
770-789	1-8		1	100																
790	1-8		1	100																
791	1-8		1	20	15	20	35	20	7	20	8	20								
792-799	1-8		1	100																

* NA = Not Applicable.

Table 28

Visibility Data in Terms of Recognition Factor Class

Visibility Code	Recognition Factor Class			
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
1	1	1	1	1
2	2	2	2	2
3	3	3	3	3
4	4	4	4	4
5	5	5	5	5
6	6	6	6	6
7	7	7	7	7
8	8	8	8	8
9	6	8	6	4
10	5	7	5	3
11	4	6	4	2
12	3	5	3	1
13	2	4	2	1
14	1	2	1	1
15	7	3	3	4
16	6	2	2	3
17	5	1	1	2
18	4	1	1	2
19	2	1	1	2
20	1	2	2	1
21	2	3	3	2
22	3	4	4	3
23	3	5	5	3
24	3	6	6	3
25	1	3	2	1
26	2	4	3	2
27	2	5	4	2
28	2	6	5	2
29	3	5	4	3
30	3	6	5	3
31	1	2	3	1
32	2	3	4	2
33	2	4	5	2
34	2	5	6	2
35	3	4	5	3
36	3	5	6	3

Table 29

Distribution of Visibility Codes Based on Land Use and Slope

Land-Use Code	Slope Class	Assigned Visibility Parameters																					
		Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%
21X	1-3	1*	20	2	20	20	20	3	20	22	20												
	4-8	1	16	2	12	20	12	3	12	21	12	22	12	23	12	24	12						
22X	1-3	1	20	2	20	26	20	3	20	21	20												
	4-8	1	15	2	14	20	14	3	14	21	14	4	14	5	14								
23X	1-3	1	20	2	16	20	16	3	16	22	16	4	16										
	4-8	1	12	2	11	20	11	3	11	21	11	22	11	23	11	24	11	4	11				
31X	1-3	1	16	2	14	20	14	3	14	22	14	21	14	22	14								
	4-8	1	16	2	12	20	12	3	12	21	12	22	12	23	12	24	12						
32X	1-3	1	20	2	16	20	16	3	16	21	16	4	16										
	4-8	1	16	2	12	20	12	3	12	21	12	4	12	5	12	6	12						
33X	1-3	1	16	2	14	20	14	3	14	22	14	4	14	5	14								
	4-8	1	10	2	9	20	9	3	9	21	9	22	9	23	9	24	9	4	9	5	9	6	9
400, 401	1-8	1	25	2	25	20	25	21	25														
402	1-8	2	25	3	25	21	25	22	25														
403	1-8	21	25	21	25	22	25	23	25														
407, 408	1-8	1	20	2	20	21	20	22	20	23	20												
500	1-8	20	34	21	33	22	33																
501	1-8	20	34	21	33	222	33																
503	1-8	21	34	22	33	23	33																
507	1-8	1	20	2	20	21	20	22	20	23	20												
610, 613	1-8	3	20	4	16	5	16	22	16	23	16	24	16										
620, 621, 625, 627	1-8	2	20	3	20	4	20	20	20	21	20												
623	1-8	2	20	3	16	4	16	5	16	21	16	22	16										
622, 624, 626, 628, 629	1-8	2	20	3	16	20	16	21	16	22	16	23	16										

(Continued)

* See Table 22 for visibility code identification.

Table 29 (Concluded)

Land-Use Code	Slope Class	Assigned Visibility Parameters																					
		Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%	Code	%
63X	1-3	20	34	21	33	22	33																
64X	1-3	20	34	21	33	22	33																
710-729	1-8	3	34	4	33	5	33																
730-739	1-8	1	100																				
740-769	1-8	3	20	4	16	5	16	6	16	7	16	8	16										
770-789	1-8	1	100																				
790, 791	1-8	3	25	4	25	5	25	6	25														
792-799	1-8	3	20	4	20	5	20	6	20	7	20												

Table 30

Example Legend of Terrain Descriptions for AMM

Terrain Unit	AMM Soil Type	Soil Strength, CI Dry	Avg	Wet	Wet-Wet	Approach Angle deg	Obstacle Parameters Magnitude in.	Width in.	Length ft	Spacing ft	Type*	Surface Roughness rms El in.	Stem Spacing, ft, by Stem Diameter, in. 0	>1	>2.4	>3.9	>5.5	>7.0	>8.7	>9.9	Visibility, ft Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
105	1	300	280	60	40	110	8	24	4	7	1	0.5	22	22	31	31	51	51	51	66	175	175	175	175
120	1	300	215	30	21	139	12	17	100	150	2	3.8	4	11	16	22	22	31	31	31	50	50	50	50
330	1	200	160	55	36	187	5	40	75	198	2	0.8	328	328	328	328	328	328	328	328	70	35	35	70
333	1	200	160	65	38	152	4	29	63	5	2	0.3	328	328	328	328	328	328	328	328	110	55	55	110
401	1	240	200	60	45	205	28	39	70	17	2	1.0	4	4	16	16	328	328	328	328	70	35	35	70
402	1	230	225	45	34	197	9	68	87	128	2	1.5	4	11	16	22	31	31	51	51	250	130	130	250
403	1	300	280	45	33	219	17	42	32	31	1	0.6	31	31	31	31	31	31	51	66	250	18	18	52
500	1	300	280	36	28	207	39	125	90	52	2	2.0	16	16	16	16	16	16	16	16	250	130	130	250
501**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
507	4	255	180	85	55	187	13	18	99	130	2	0.7	328	328	328	328	328	328	328	328	250	130	130	250
621	4	240	180	75	60	140	3	29	50	5	2	1.1	328	328	328	328	328	328	328	328	70	35	35	70

* 1 = random, 2 = linear.
** Urban code - 1.

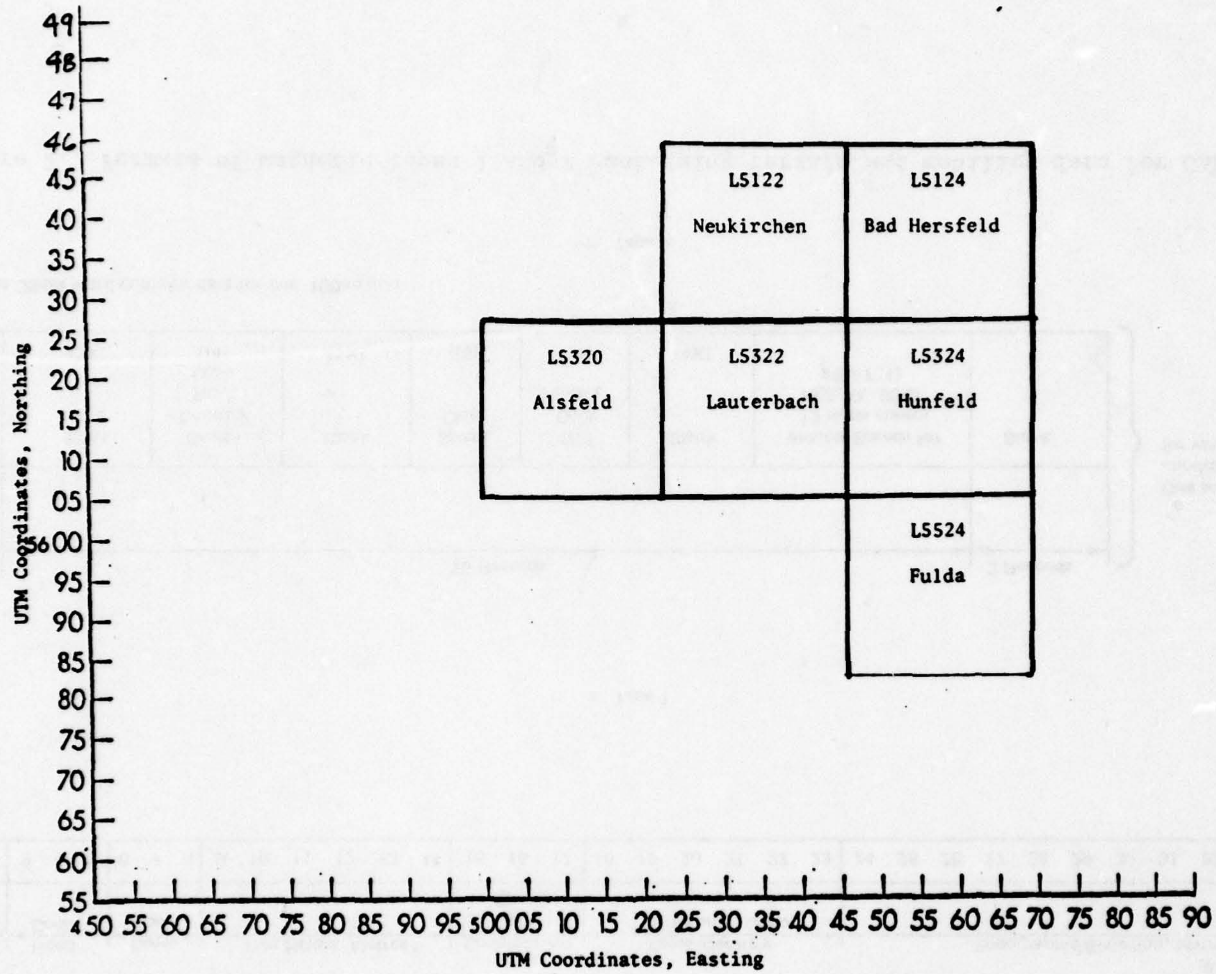
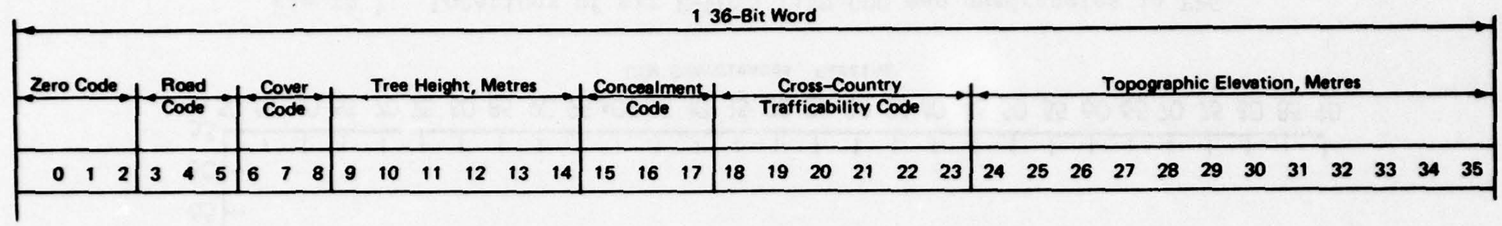
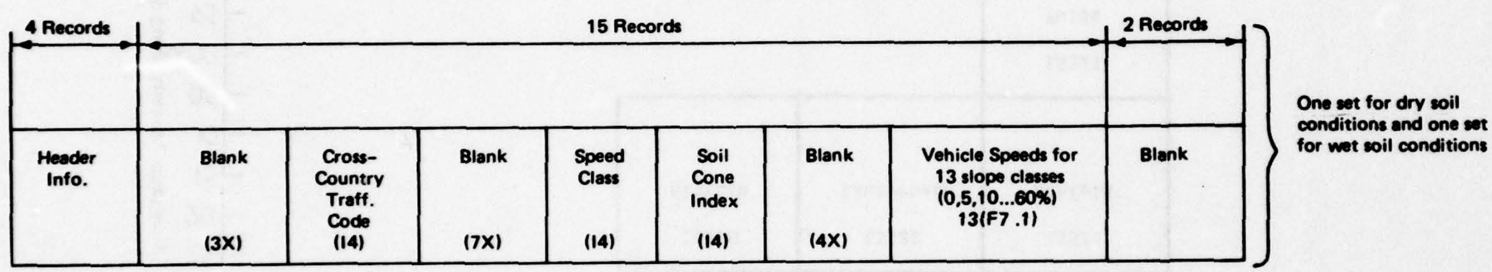


Figure 1. Locations of six E-FOSS 1:50,000 map quadrangles in FRG



a. Tape 1



NOTE: One 36-bit word contains data for one 100-m grid.

b. Tape 2

Figure 2. Formats of magnetic tapes 1 and 2 containing terrain and mobility data for CARMONETTE

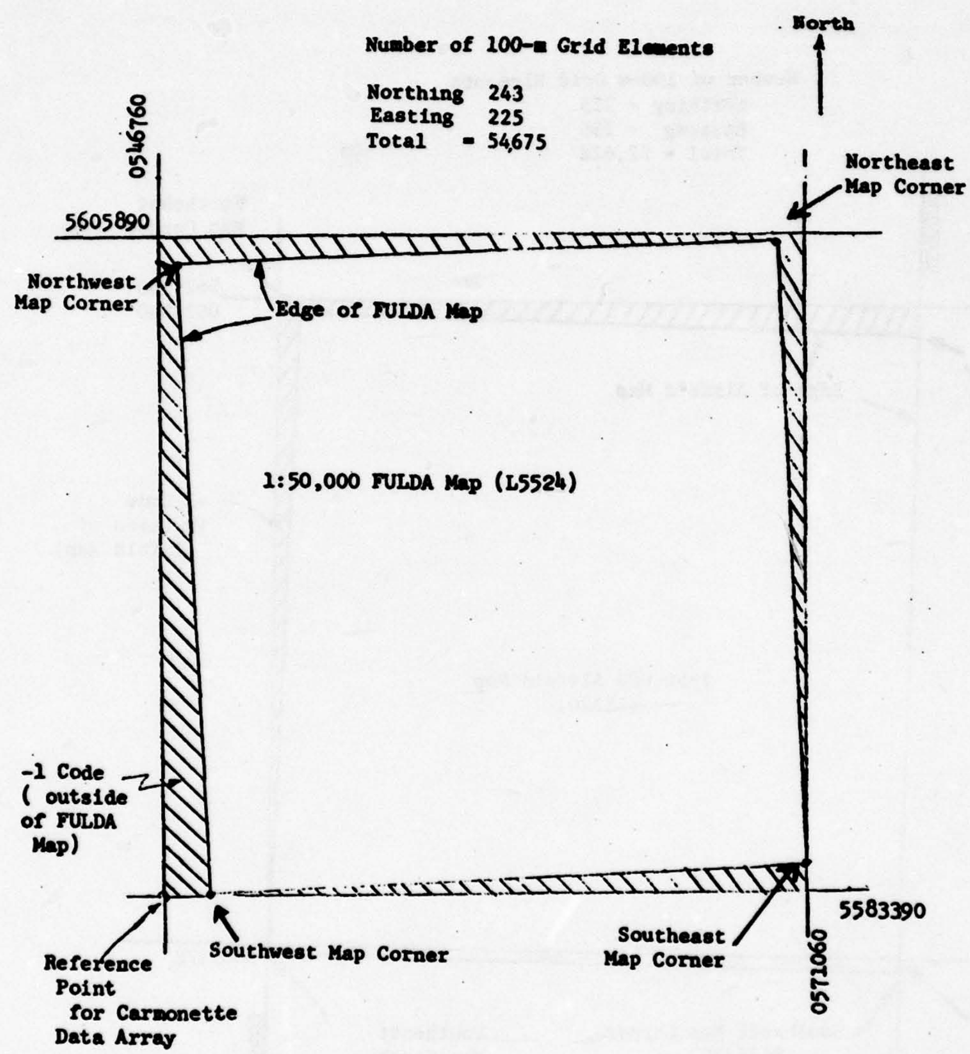


Figure 3. CARMONETTE data array for Fulda quadrangle (L5524)

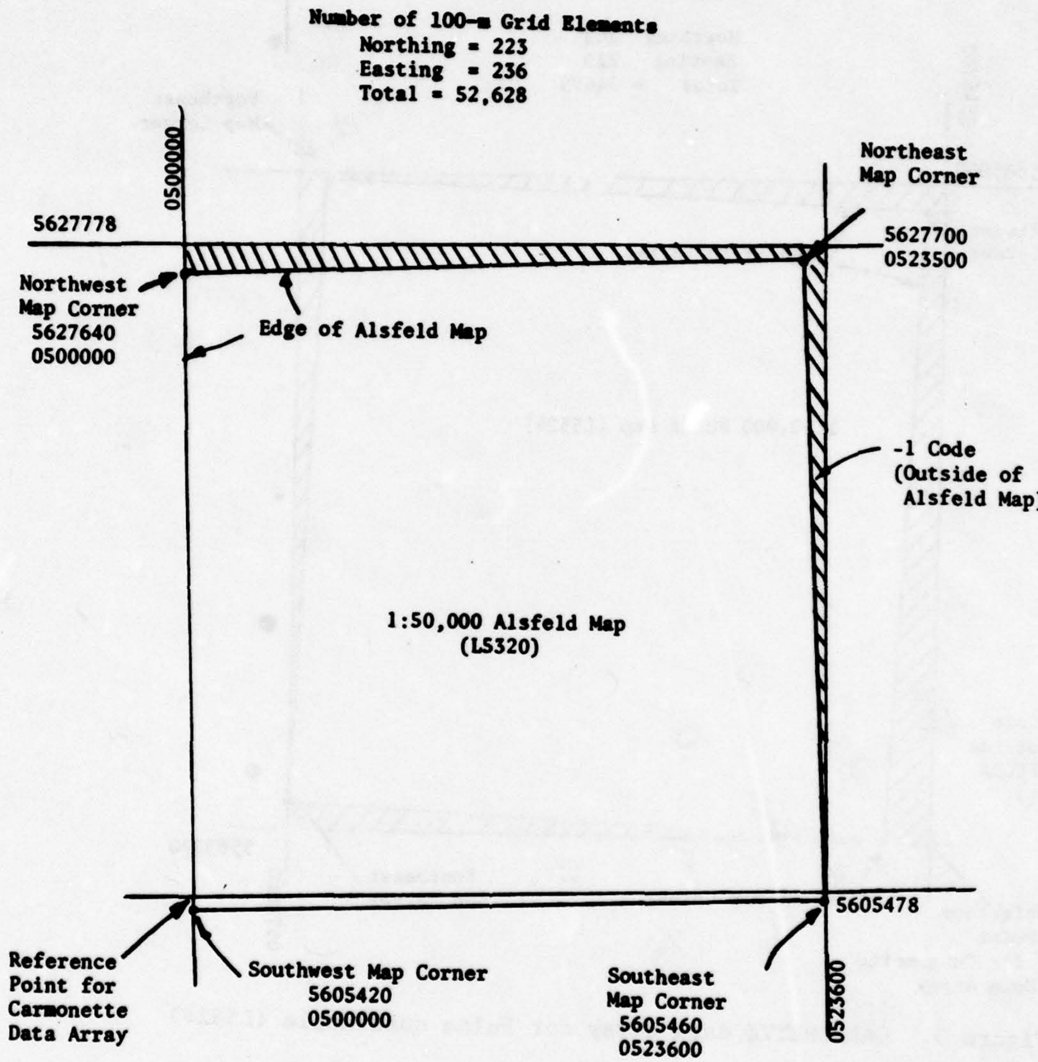


Figure 4. CARMONETTE data array for Alsfeld quadrangle (L5320)

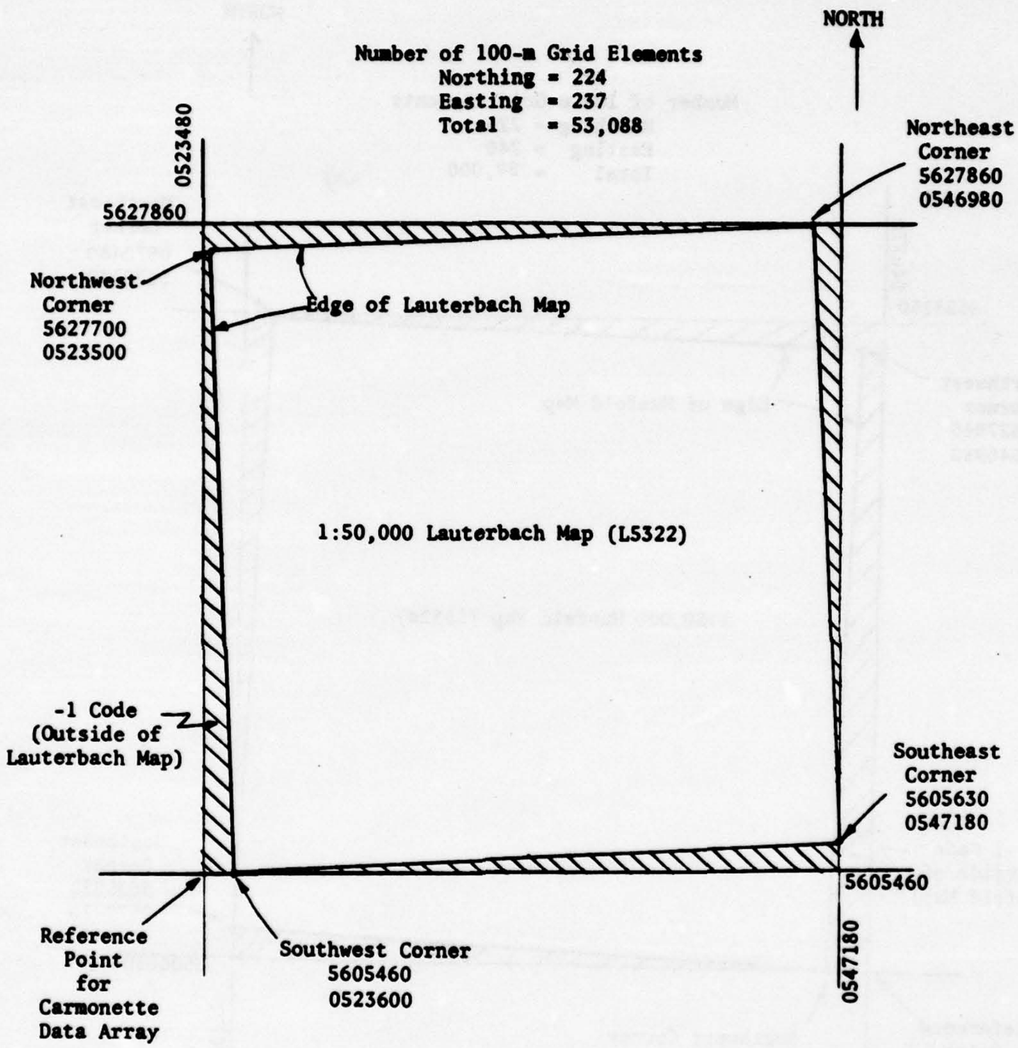


Figure 5. CARMONETTE data array for Lauterbach quadrangle (L5322)

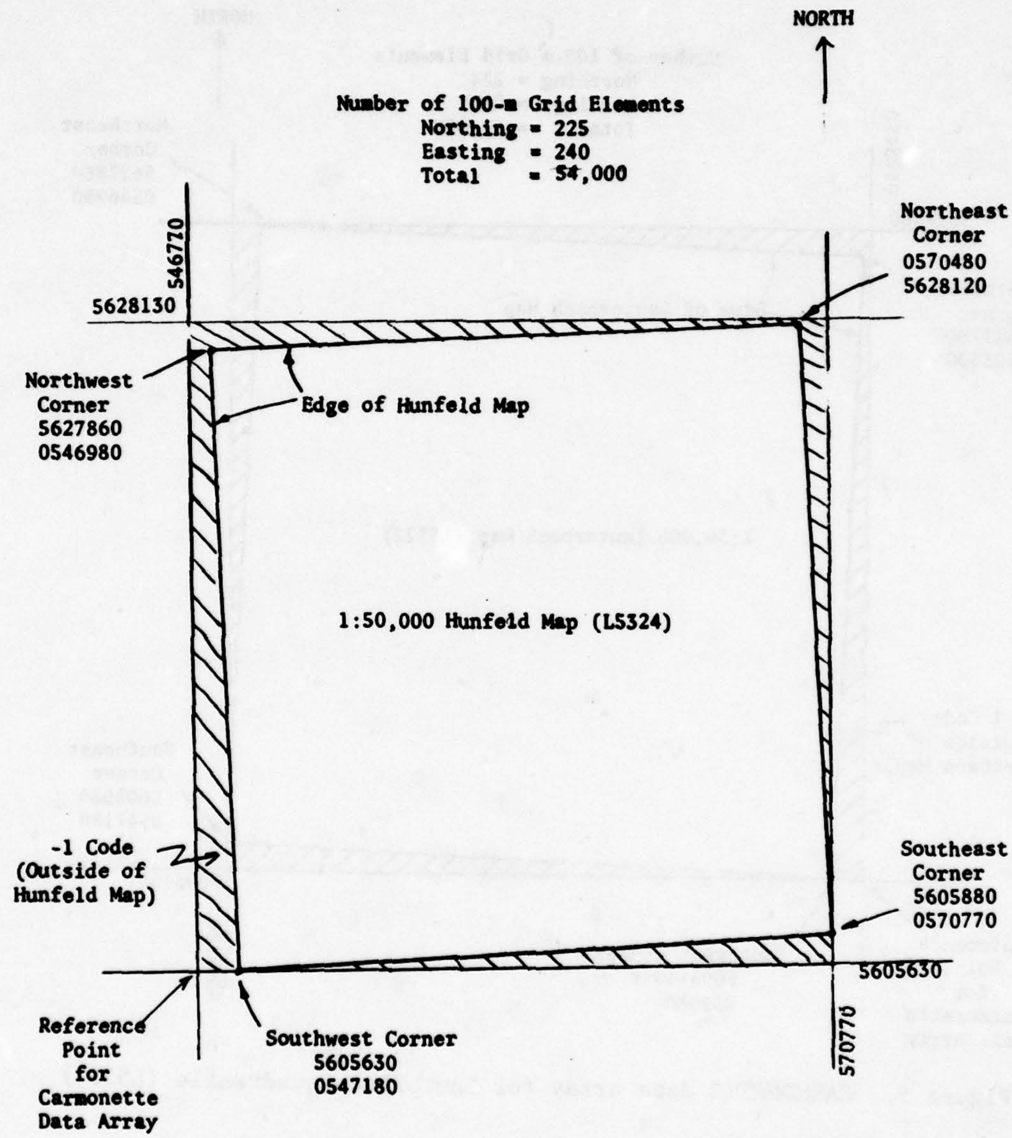


Figure 6. CARMONETTE data array for Hunfeld quadrangle (L5324)

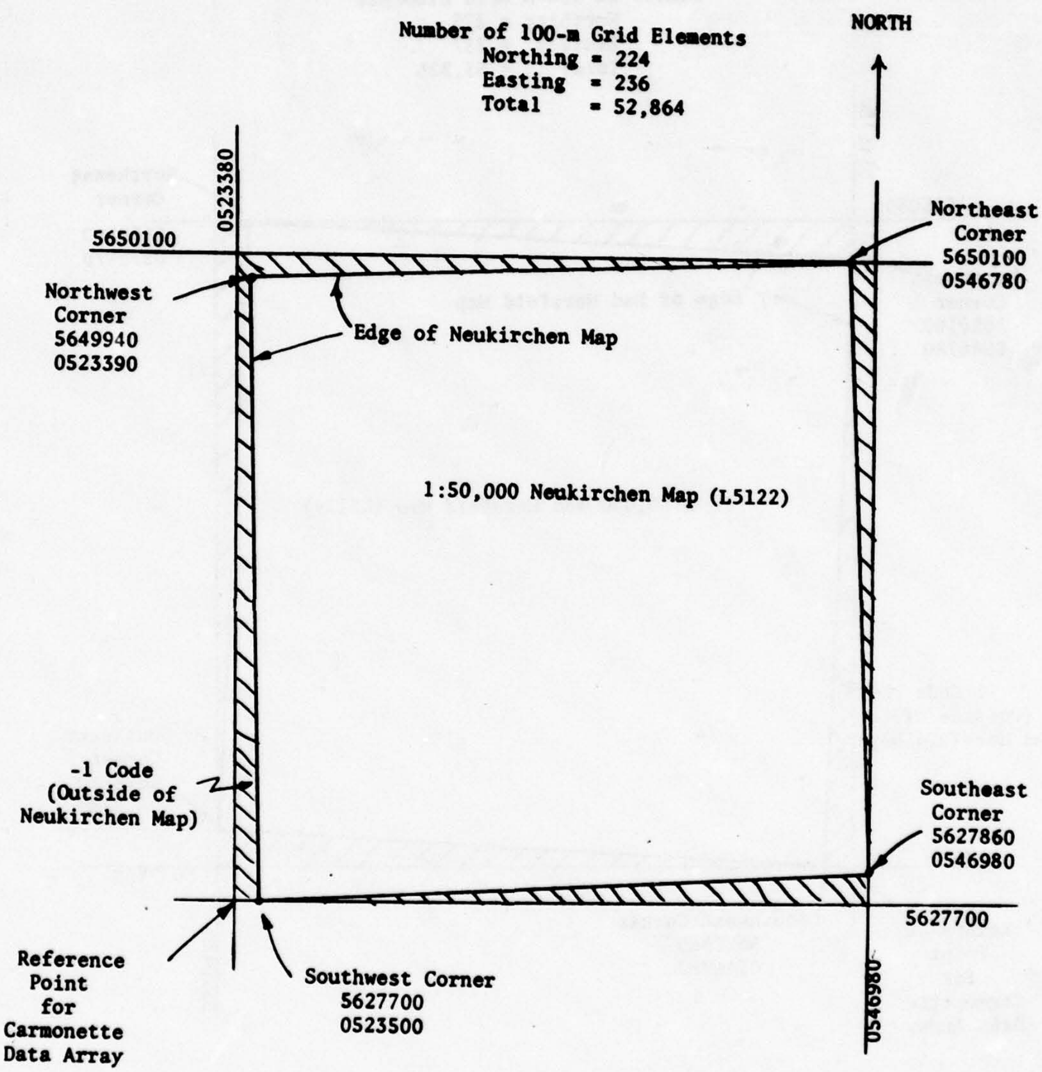


Figure 7. CARMONETTE data array for Neukirchen quadrangle (L5122)

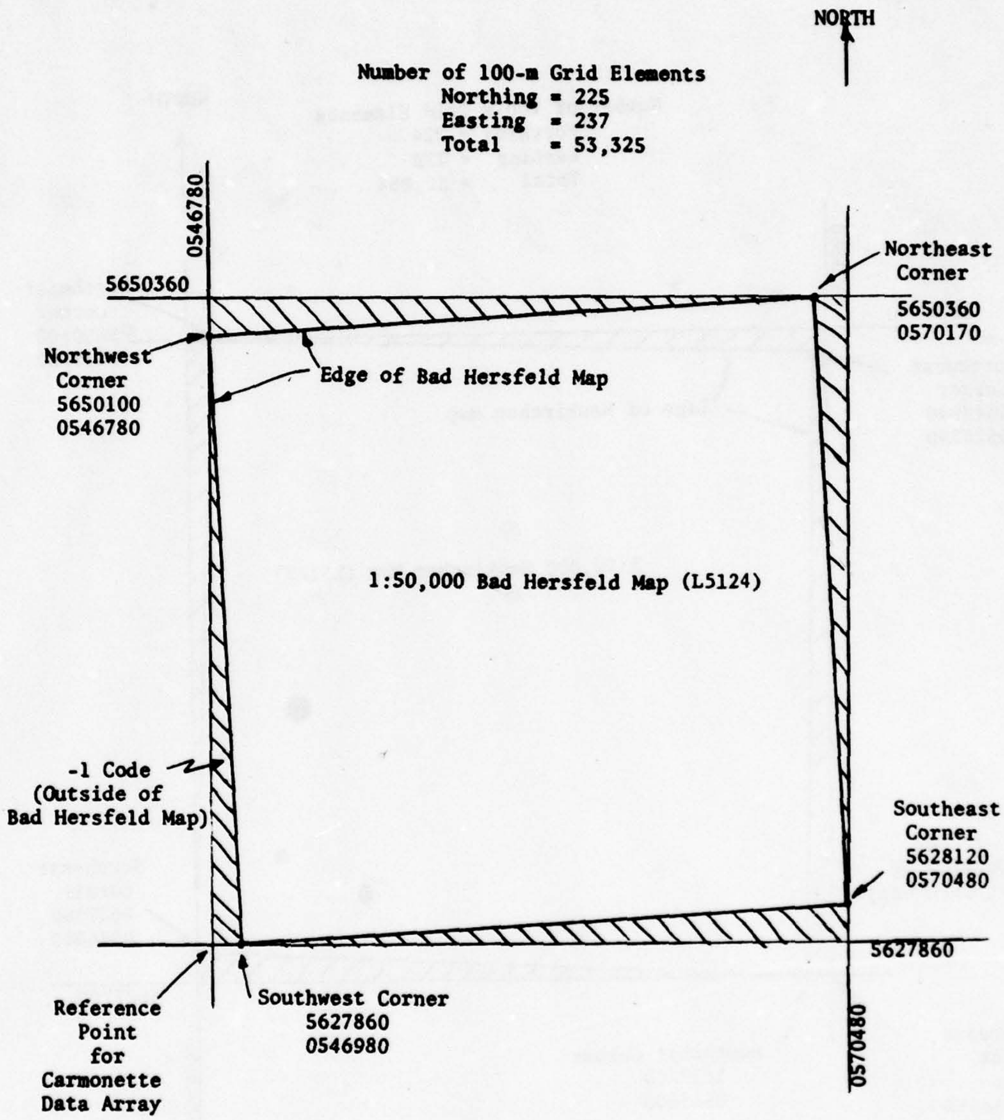


Figure 8. CARMONETTE data array for Bad Hersfeld quadrangle (L5124)

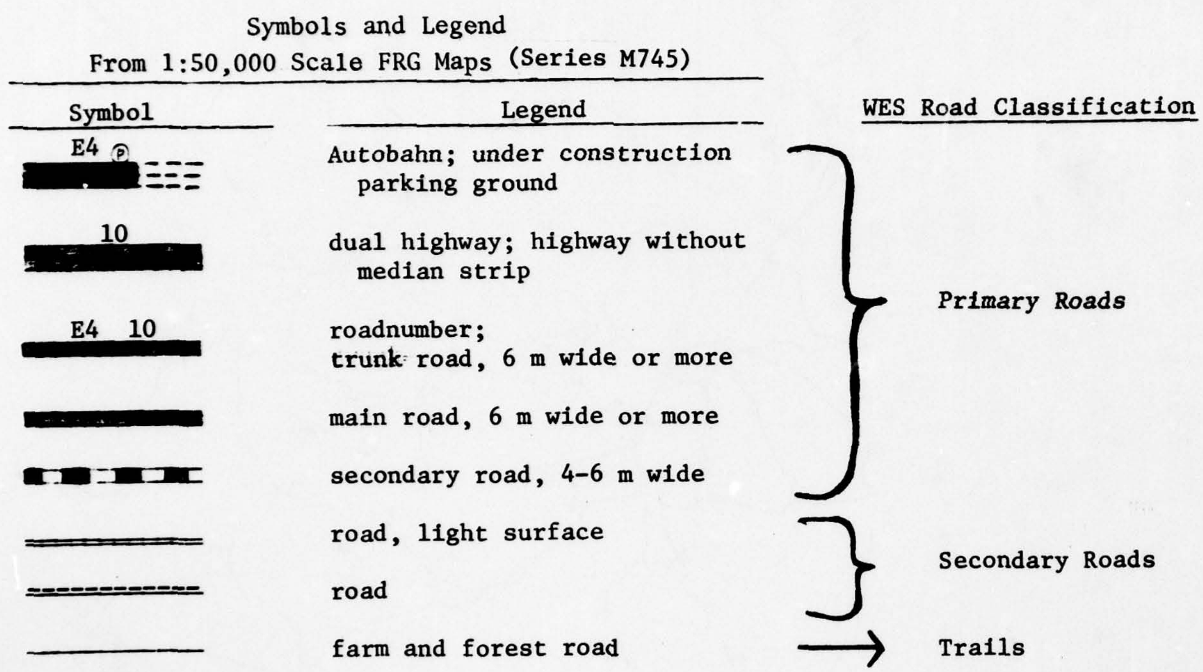


Figure 9. WES road categories used for E-FOSS

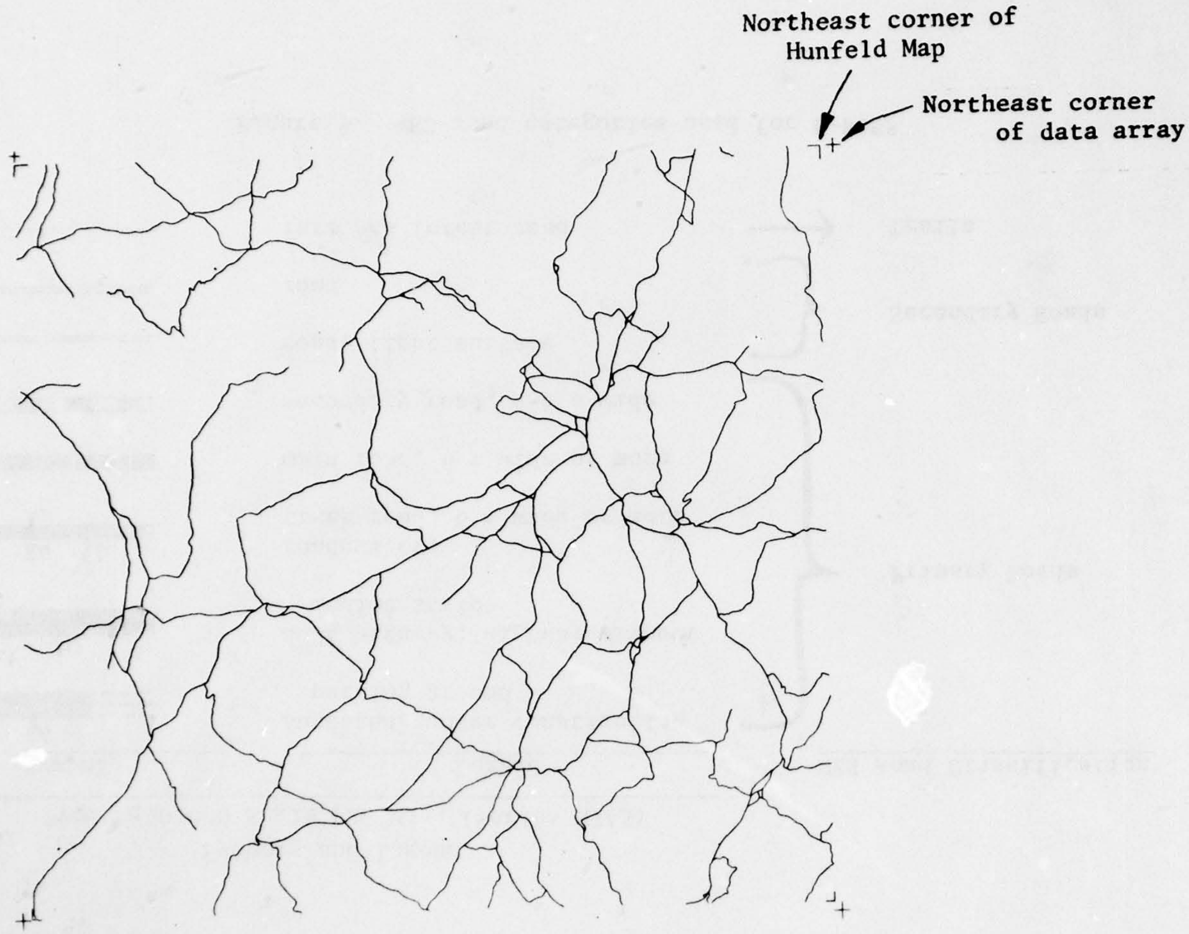


Figure 10. Primary roads on 1:50,000 Hunfeld map

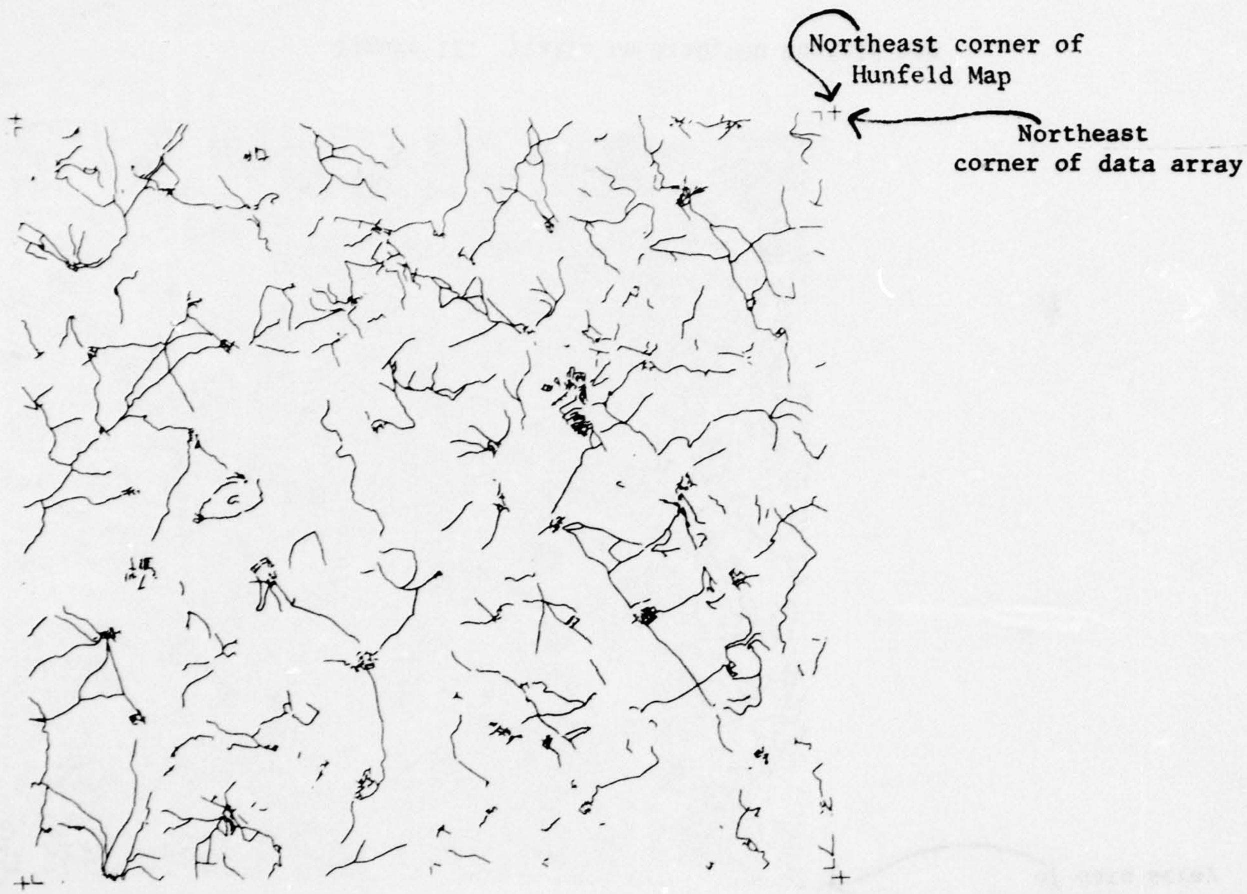


Figure 11. Secondary roads on 1:50,000 Hunfeld map

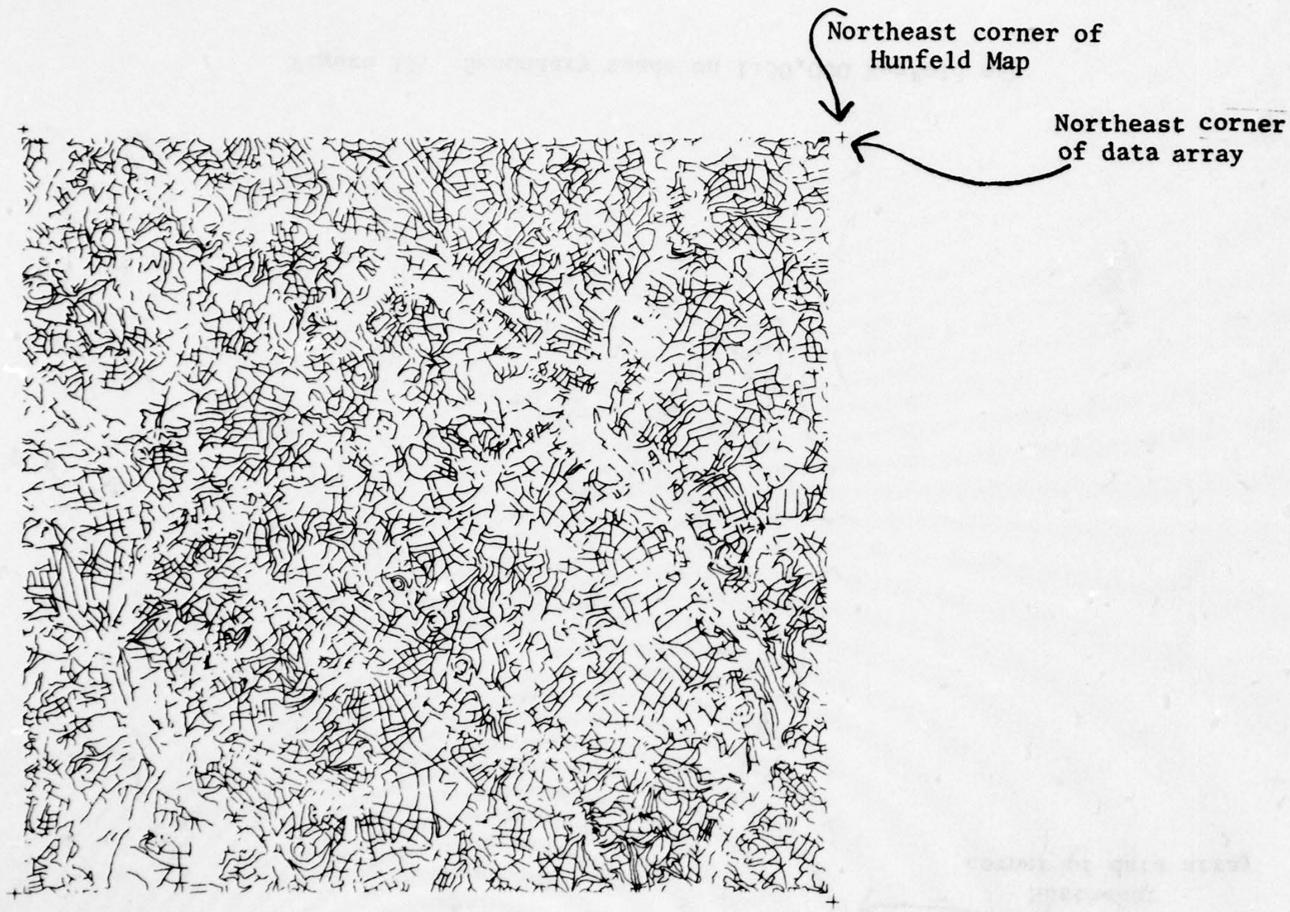
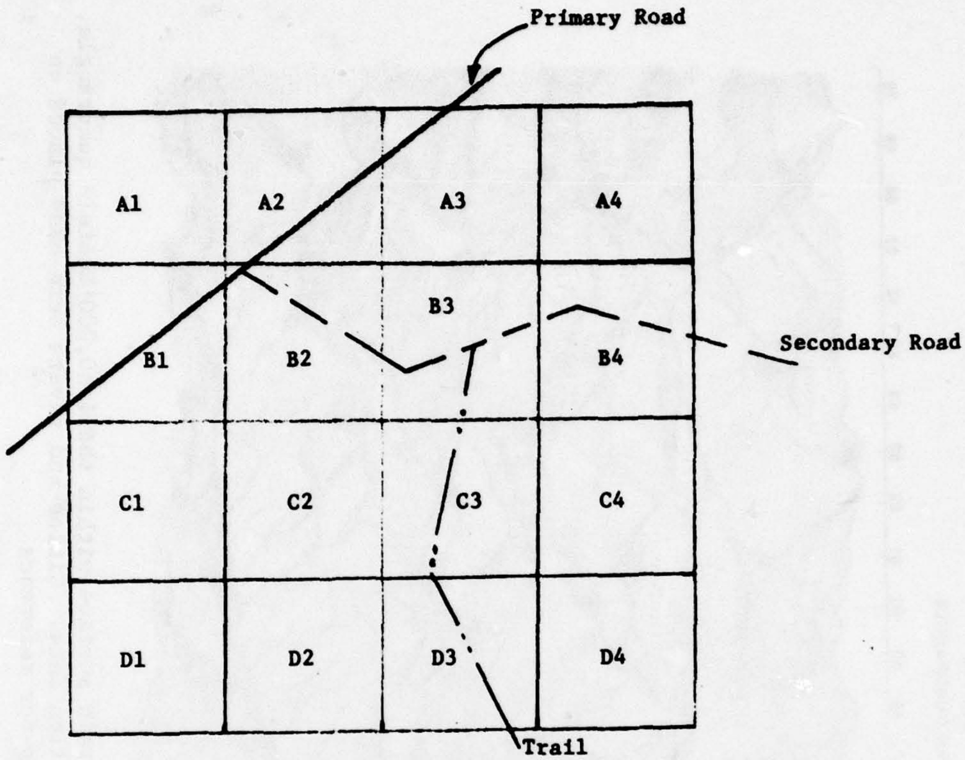


Figure 12. Trails on 1:50,000 Hunfeld map



Grid Squares	Road Type	Code
A1, A4, C1, C2, C4, D1, D2, D4	No road	0
A2, A3, B1	Primary road	1
B4	Secondary road	2
C3, D3	Trail	3
B2	Primary and Secondary roads	4
None	Primary and Trail	5
B3	Secondary and Trail	6
None	Primary, Secondary, and Trails	7

Figure 13. Illustration of classification of grid squares according to one of eight possible road codes

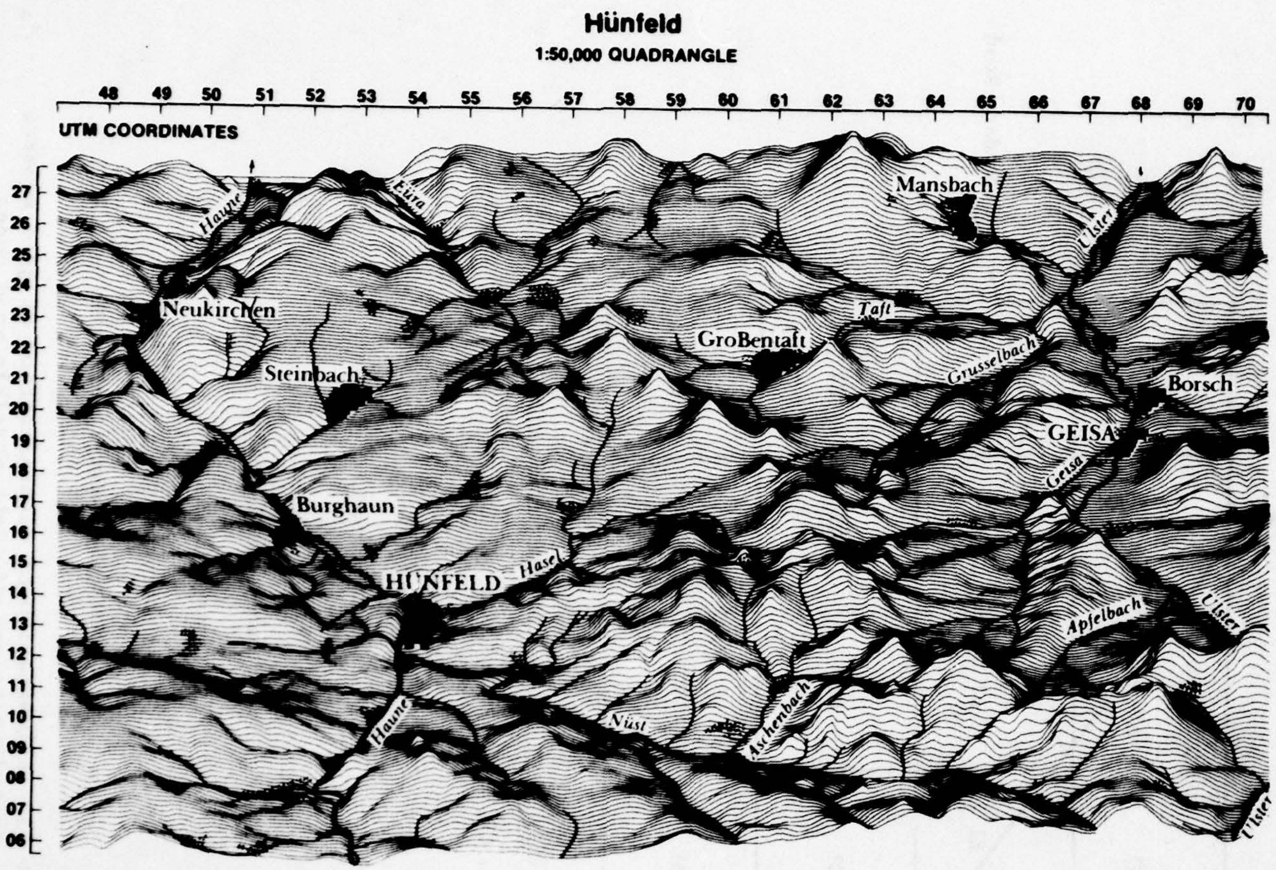


Figure 14. Computer-drawn plot of the terrain surface within the 1:50,000 Hunfeld quadrangle. Plot constructed using 100-m gridded elevation data. Cities and rivers were hand placed on the map for reference

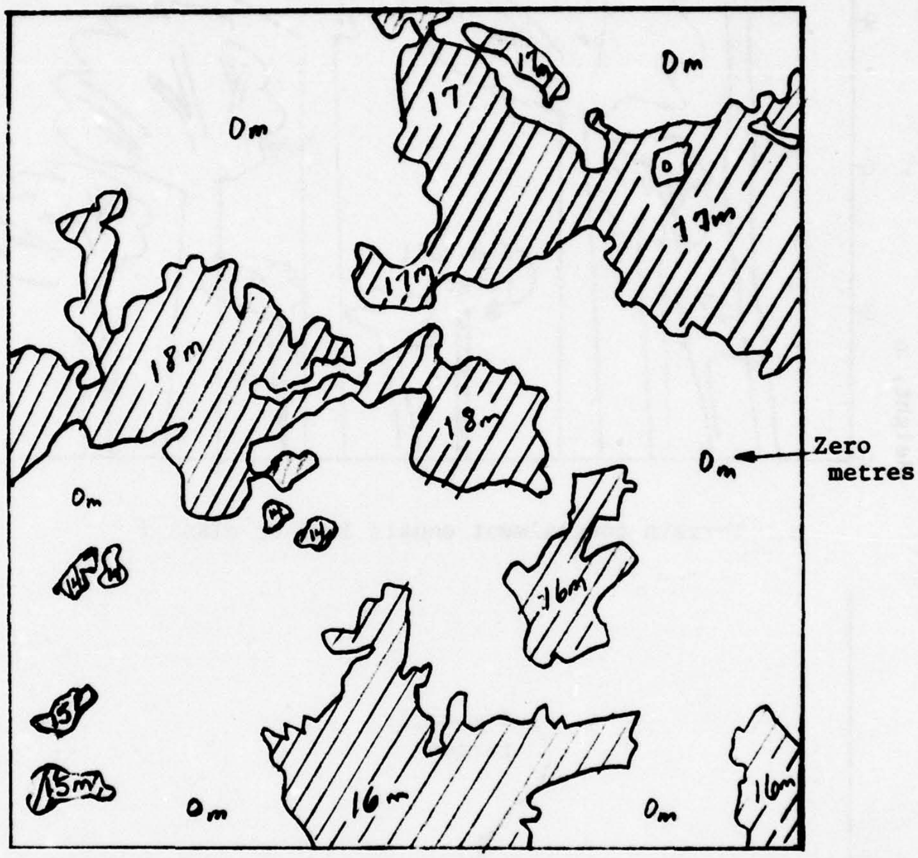
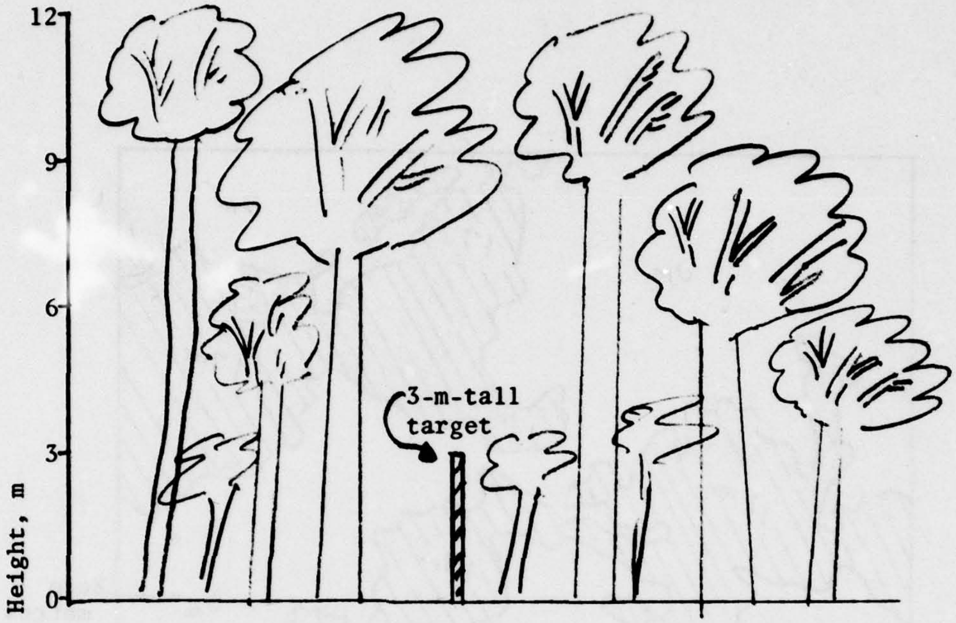
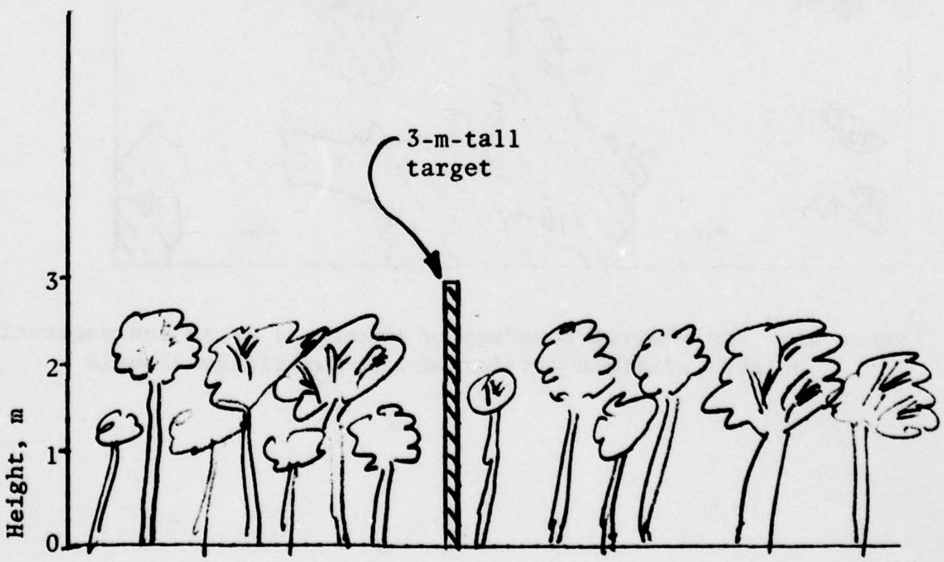


Figure 15. Map showing boundary of vegetated areas and vegetation heights within a portion of the Hunfeld quadrangle



a. Terrain concealment equals 100% or class 7



b. Terrain concealment equals 2.6/3.0 = 87% or class 6

Figure 16. Determinations of terrain/target concealment

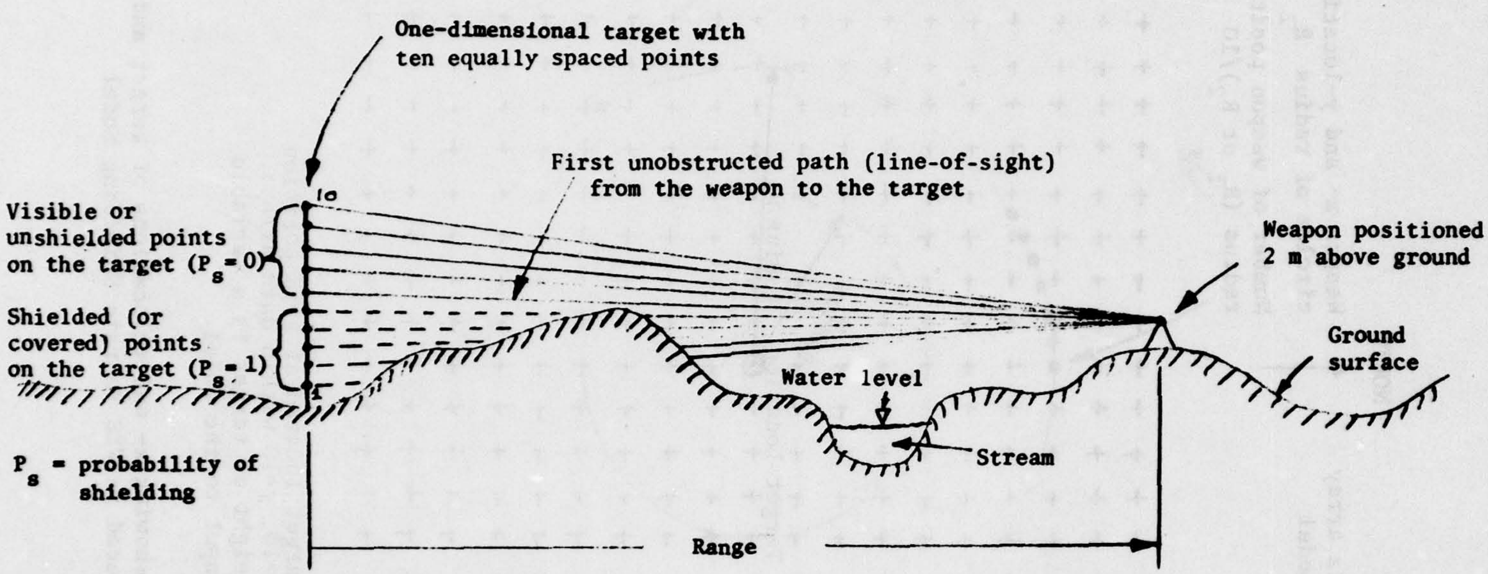
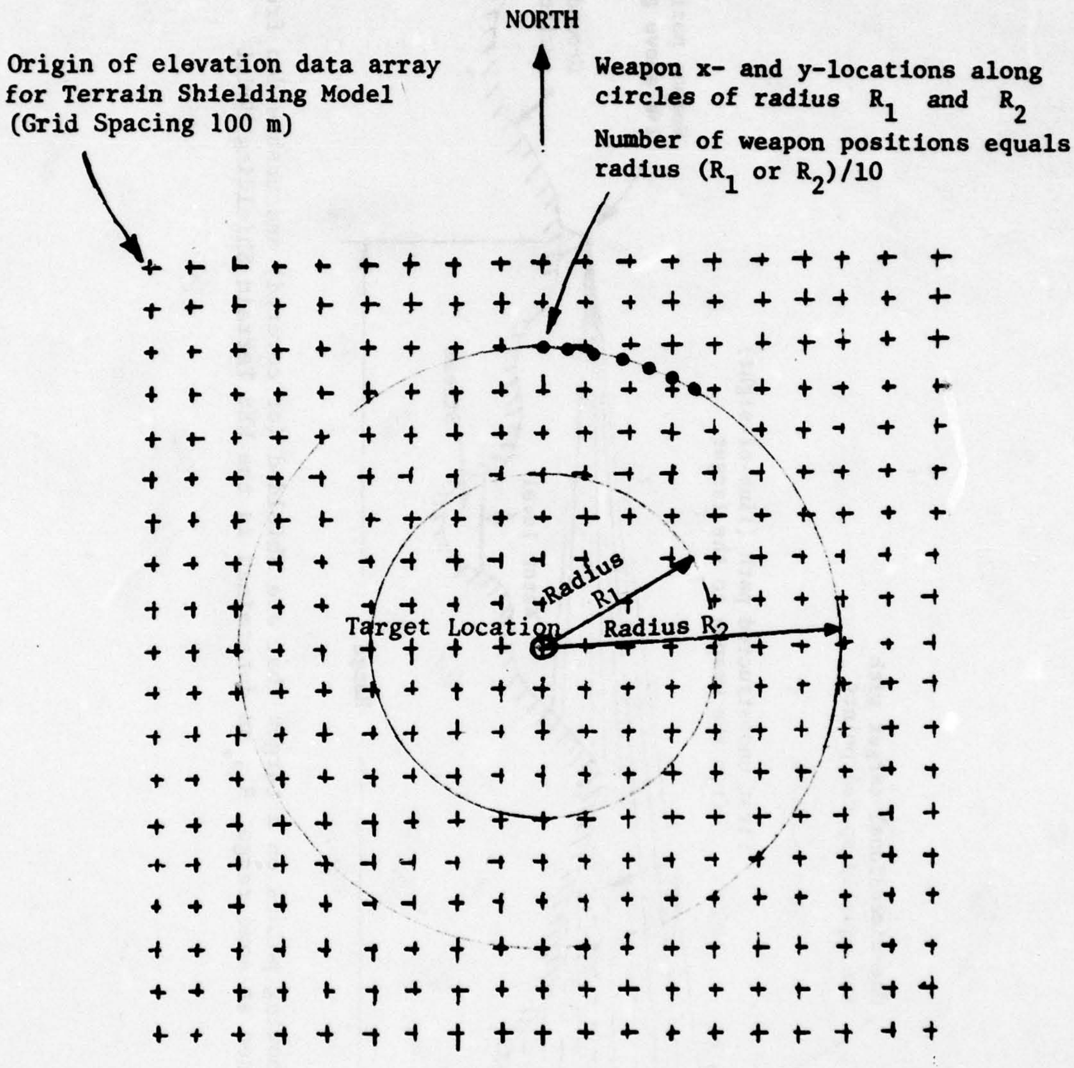


Figure 17. Sketch showing points on a target that are shielded (or covered) and unshielded from a weapon, positioned at some range R , as determined in the WES Terrain Shielding Model



NOTE: Target located at grid position x=10, y=10 within data array; height of target is a variable input to the model

Figure 18. Sketch showing x- and y-locations of target and weapons as considered in WES Terrain Shielding Model

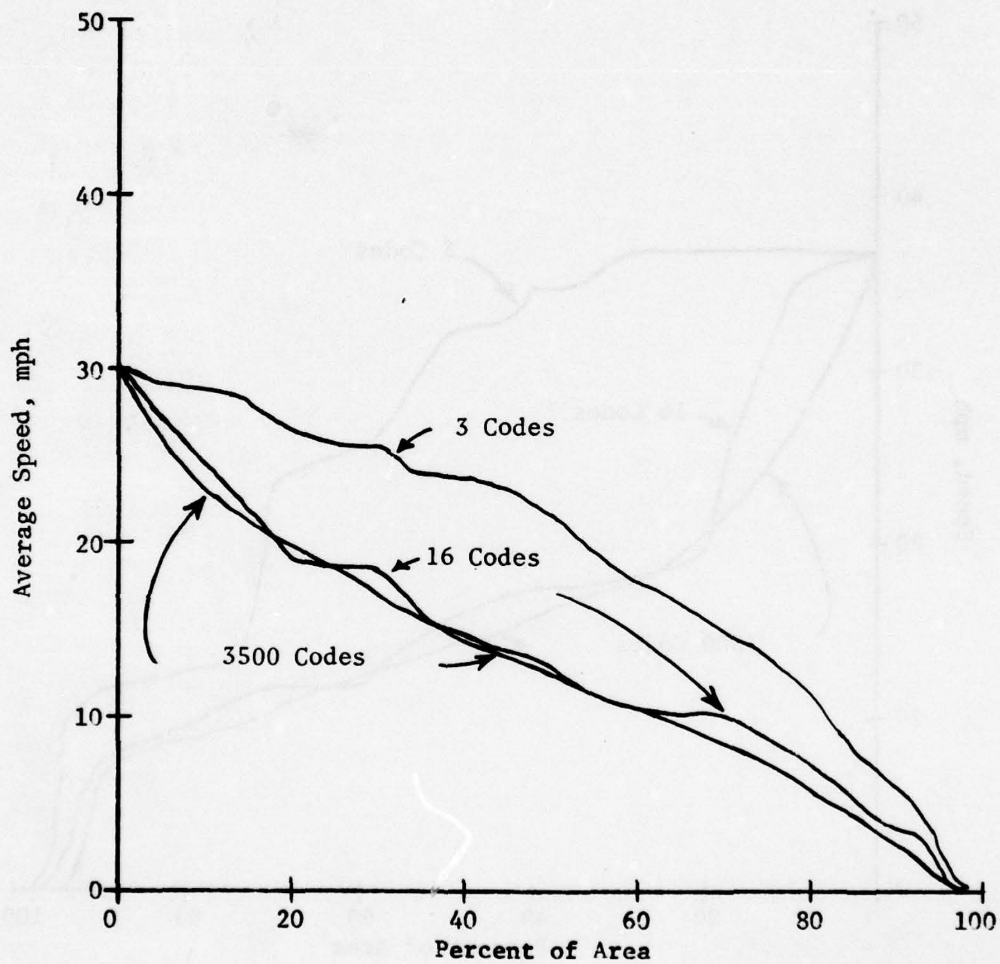


Figure 19. Speed established for M60A2 using 3, 16, and 3500 mobility codes for dry condition of Fulda quadrangle (L5524)

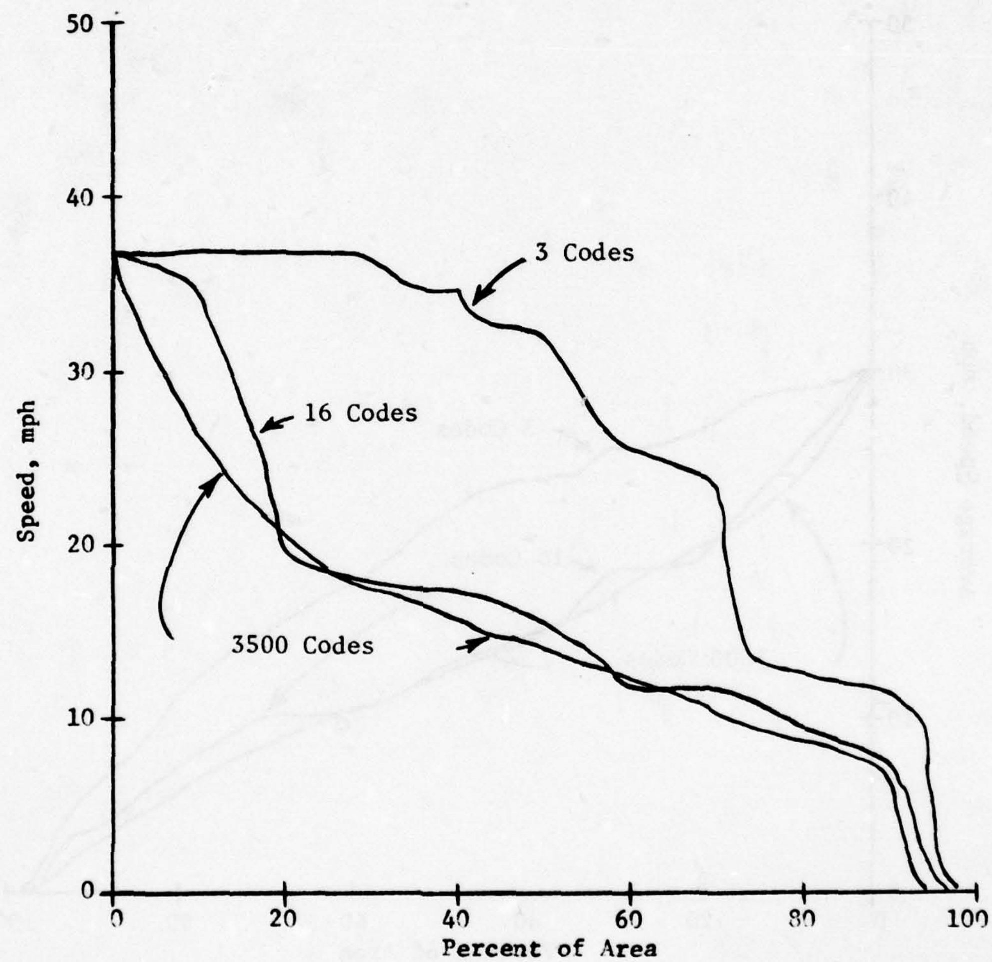
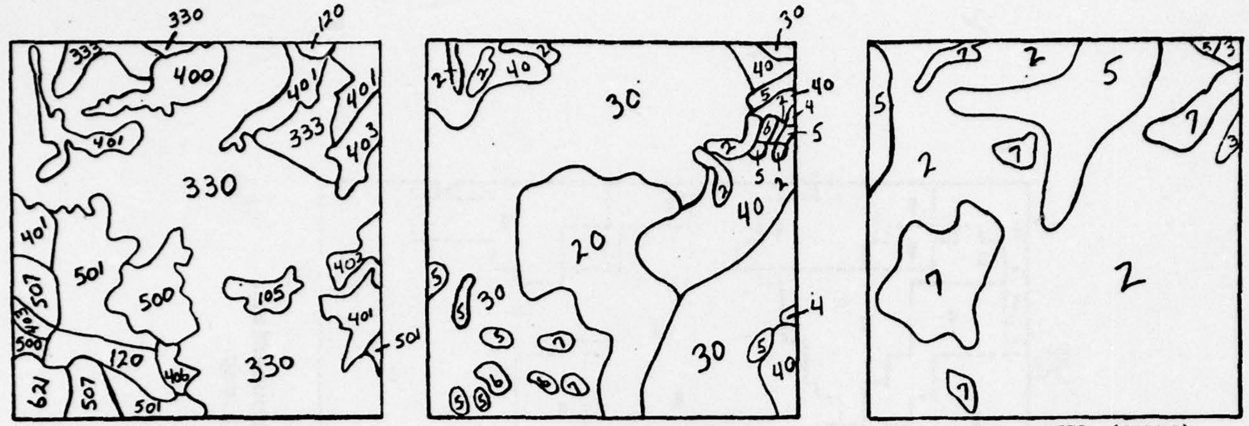
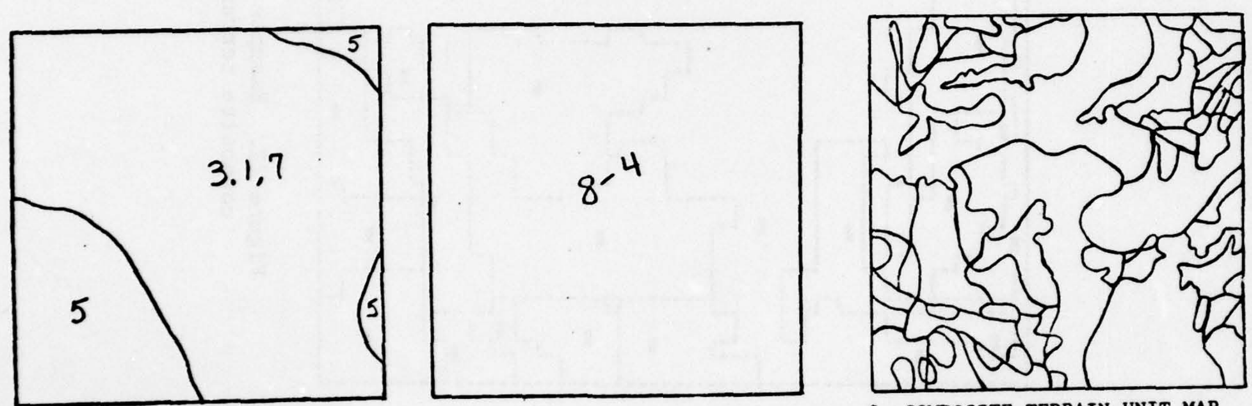


Figure 20. Speed established for BMP using 3, 16, and 3500 mobility codes for dry condition of Fulda quadrangle (L5524)



a. LAND USE (CODES)
b. SLOPE MAGNITUDE (DEGREES)
c. SOILS (CODES)



d. VEGETATION (CODES)
e. SURFACE GEOLOGY (CODES)
f. COMPOSITE TERRAIN UNIT MAP (i.e. 5 factor maps combined into single map)

Figure 21. Example of individual terrain maps and composite terrain unit map

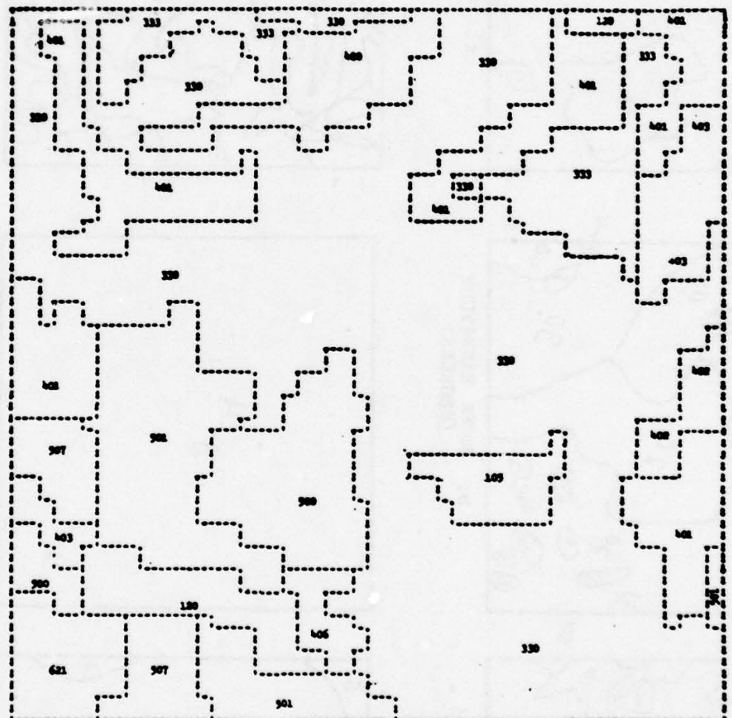


Figure 22. Example of computerized composite terrain unit map

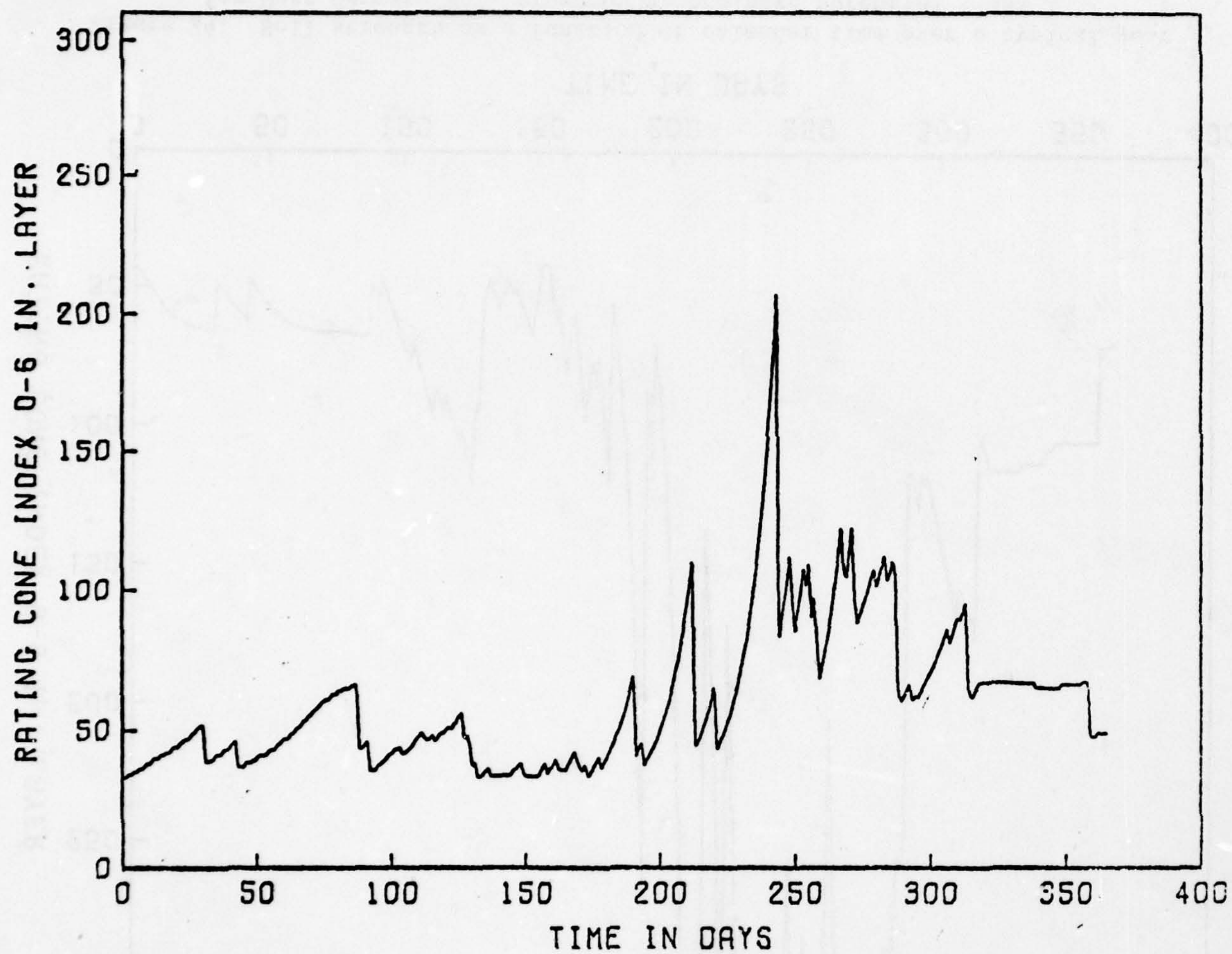


Figure 23. Soil strength as a function of calendar time over a typical year for West Germany soil group 0808, drainage potential class 2

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DIGITAL TERRAIN AND MOBILITY DATA BASES FOR E-FOSS.(U)
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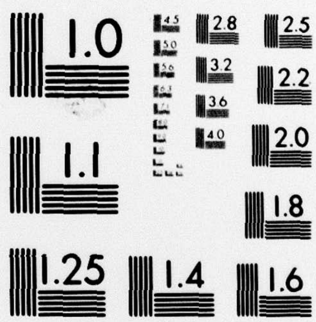

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

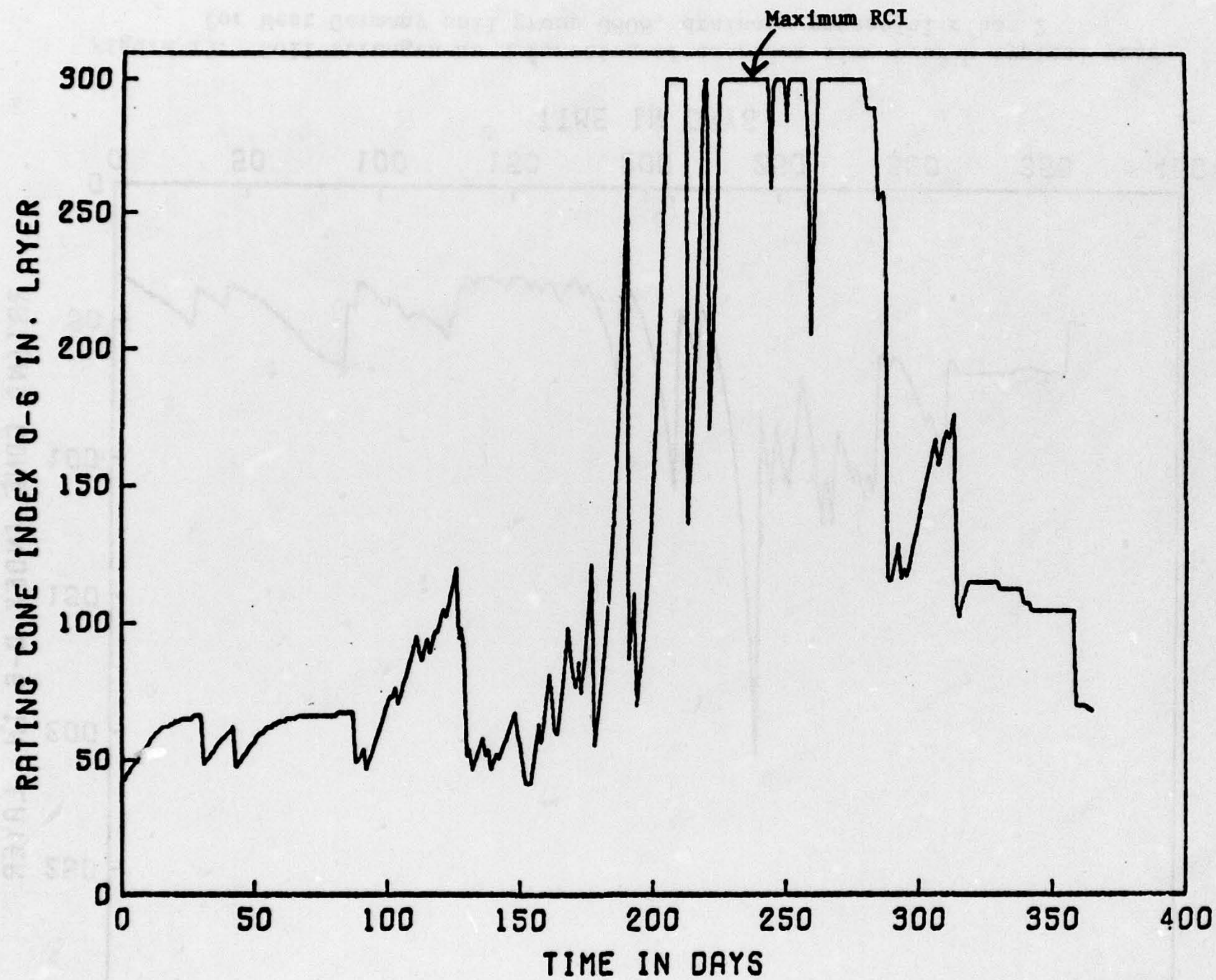

Figure 24. Soil strength as a function of calendar time over a typical year for West Germany soil group 0909, drainage potential class 1

APPENDIX A: DESCRIPTION OF SCANNER/DIGITIZER

1. The scanner/digitizer used by the U. S. Army Engineer Waterways Experiment Station (WES) for the road classification was an Optronics International, Inc., Photomation Mark II System (Figure A1). This system is an electro-mechanical, drum-type, film-scanning and film-writing system designed to accept film sizes up to and including 22.8 by 22.8 cm (9 by 9 in.). The film scanning or input mode is the mode of operation used in digitizing roads. In this mode, a film transparency is clamped to a drum so that the film adheres exactly to the machined cylindrical surface of the drum. A light source and a photodetector are mounted on opposite arms of a carriage within which the drum rotates. An opening in the drum allows light from the source to be transmitted through the transparency to the detector. As the drum rotates, the optical density of successive square spots (pixels) on the film along the circumference of the drum (y-direction) is measured at selected raster intervals. The pixel size can be selected and can be either 12.5, 25, or 50 μm in size. The raster interval is normally selected to be equal to the pixel size. After each drum revolution, the carriage is stepped in the axial (x) direction a distance equal to the raster interval, and the process is repeated until the total desired area of the film has been scanned.

2. The output of the photodetector is amplified and converted to digital form; these digital values can vary between 0 and 225.

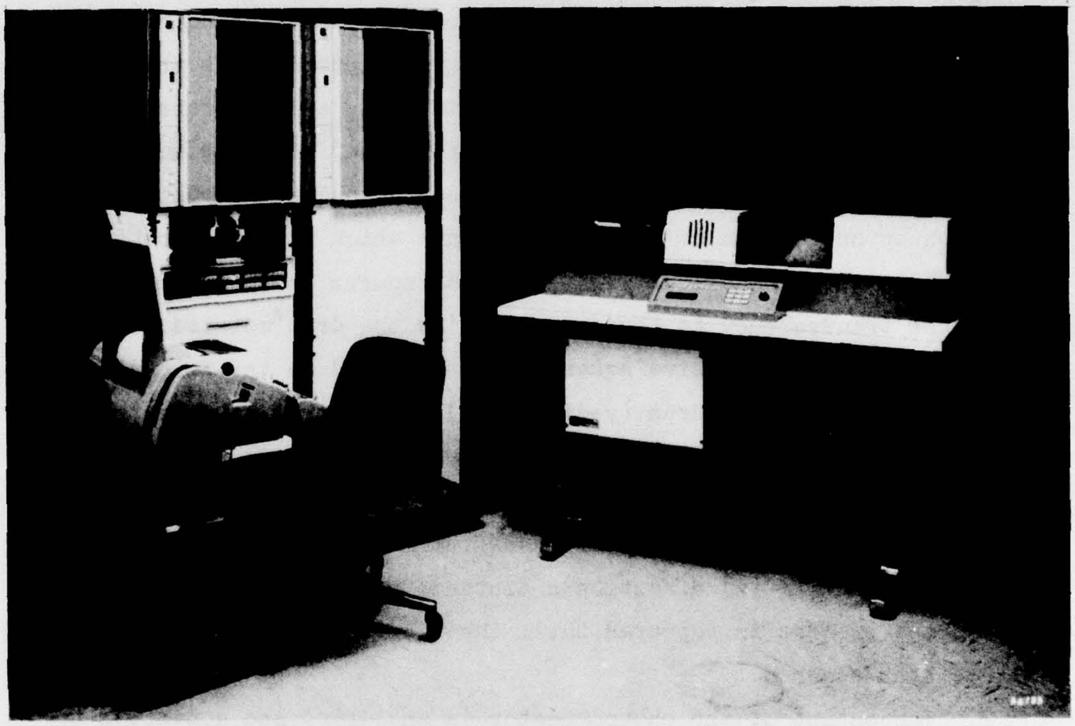

Figure A1. Optronics scanner/digitizer used to prepare road data

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

West, Harold W

Digital terrain and mobility data bases for E-FOSS / by Harold W. West, Daniel Krivitzky, and Donald D. Randolph. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1980.

32, [63] p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; EL-80-1)

Prepared for U. S. Army TRADOC Systems Analysis Activity (TRASANA), White Sands, N. Mex.; U. S. Army Engineer School, Fort Belvoir, Va.; and Office, Chief of Engineers (OCE), U. S. Army, Washington, D. C., under Engineer-Family of Systems Study (E-FOSS) and OCE Project 4A762730AT42, Task B/E4.

References: p. 32.

1. Computer applications. 2. Computerized models. 3. Digital

(Continued on next card)

West, Harold W

Digital terrain and mobility data bases for E-FOSS ... 1980. (Card 2)

systems. 4. Engineer-Family of Systems Study. 5. Mobility models. 6. Systems analysis. 7. Terrain models (Analytical). I. Krivitzky, Daniel, joint author. II. Randolph, Donald D., joint author. III. United States. Army. Corps of Engineers. IV. United States. Army TRADOC Systems Analysis Activity. V. United States. Engineer School. VI. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; EL-80-1.

TA7.W34m no.EL-80-1

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UNCLASSIFIED WES-MP/EL-80-1 NL

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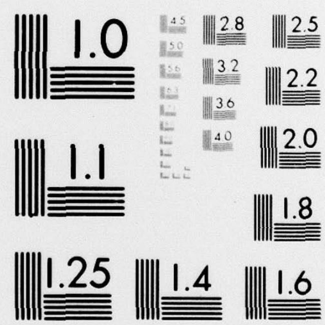

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WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESEN

15 July 1980

Errata Sheet

No. 1

DIGITAL TERRAIN AND MOBILITY DATA BASES
FOR E-FOSS

Miscellaneous Paper EL-80-1

January 1980

Table 12:

Replace this table with the inclosed corrected Table 12.

Table 12

Vehicle Characteristics Used in the Army Mobility Model (AMM)

No.	Identification	Dimensions	U. S. Comparison Vehicles: XM1	M60A1	CMICV	M113A1	Foreign Comparison Vehicles: Unnamed	T62	BMP	BRDM
1	Vehicle type (NVEH = 0) for tracked and 1 for wheeled	--	0	0	0	0	0	0	0	1
2	Gross vehicle weight	lbs	115,000.	104,000.	48,000.	24,600.	84,000.	80,000.	29,000.	15,700.
3	Track type (NFL = 0) for flexible and 1 for girderized	NA	0	0	0	0	0	0	0	NA
4	Grouser height for tracks	NA	2	2.	1	1	1	1	2	NA
5	Tire ply rating	--	NA	NA	NA	NA	NA	NA	NA	8
6	Gross rated horsepower	bhp	1,500.	643.	448.	209.	756.	580.	279.	139.
7	Number of tracks or tires	--	2.	2.	2.	2.	2.	2.	2.	4.
8	Number of axles	--	NA	NA	NA	NA	NA	NA	NA	2
9	Vehicle width	in.	141.5	143.0	126.5	105.8	134.0	130.0	116.0	92.5
10	Vehicle length	in.	307.0	273.0	251.6	192.0	268.0	259.0	264.0	227.0
11	Track width or nominal tire width	in.	25.0	28.0	21.0	15.0	22.8	22.8	11.7	13.0
12	Wheel rim diameter on road wheel radius	in.	NA	NA	NA	NA	NA	NA	NA	18.0
13	Recommended tire pressure (cross-country)	psi	NA	NA	NA	NA	NA	NA	NA	17
14	Area of one-track shoe (tracked) or number of wheels (wheeled) (duals as one)	sq in. or #	193.7	194.0	126.0	90.0	125.0	125.4	65.0	4
15	Number of bogies (tracked) or chain indicator wheeled (0 = no chains; 1 = chains)	--	14	12	12	10	12	10	12	0
16	Vehicle ground clearance at the center of greatest wheel span	in.	NA	NA	NA	NA	NA	NA	NA	14.7
17	Minimum vehicle ground clearance	in.	19.0	18.0	17.2	16.0	18.0	16.0	15.7	11.5
18	Rear end clearance (vertical clearance of vehicle's trailing edge)	in.	36.5	40.0	31.0	24.5	20.0	20.0	15.5	25.0
19	Vehicle departure angle	deg	38.0	42.5	77.5	40.0	70.0	59.0	56.0	38.0
20	Vehicle approach angle	deg	58.0	90.0	82.0	70.0	90.0	55.0	28.0	40.0
21	Length of track on ground or wheel diameter	in.	183.5	171.0	152.0	109.0	173.0	164.0	141.0	43.6
22	Height of vehicle pushbar, bumper or leading edge	in.	44.5	45.0	42.0	30.0	35.0	34.0	54.0	54.5
23	Distance between first and last wheel center lines	in.	180.5	167.0	149.0	105.0	170.0	161.0	138.0	122.3
24	Horizontal distance from the center of gravity to the front wheel center lines	in.	87.1	109.0	71.3	52.0	86.0	115.0	78.5	62.3
25	Vertical distance from the center of gravity to the road wheel center lines	in.	36.4	36.0	27.8	24.0	34.0	32.5	26.0	20.5
26	Maximum span between adjacent wheel center lines	in.	NA	NA	NA	NA	NA	NA	NA	44.0
27	Vertical distance from the ground to center of rear wheel (idler or sprocket for tracked vehicle)	in.	35.8	43.0	28.7	20.0	32.8	28.2	25.5	21.2
28	Track thickness plus the radius of the rear idler or sprocket	in.	12.9	18.0	10.5	9.8	11.0	13.0	13.2	NA
29	Road wheel radius plus track thickness	in.	15.6	13.0	14.7	14.5	14.0	18.2	13.5	NA
30	Loaded rolling radius of tire (cross-country tire pressure) or sprocket pitch radius	in.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.2
31	Height of rigid point used to determine approach angle	in.	39.3	45.0	42.0	28.2	35.0	38.0	49.5	24.2
32	Maximum breaking force the vehicle develops	lbs	44,850.	83,200.	28,800.	19,680.	50,400.	48,000.	17,400.	12,560.
33	Loaded wheel deflection (at sand tire pressure)	%	NA	NA	NA	NA	NA	NA	NA	25.
34	Distance vehicle spans before significant motion begins	in.	87.0	67.0	74.5	49.7	86.0	82.0	70.0	62.3
35	Maximum force the pushbar can withstand		230.0	185.0	55.0	55.0	160.0	200.0	70.0	15.0
36	Maximum axle loads/gross vehicle weight	--	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.510
37	Vehicle rated horsepower per ton	hp/ton	26.1	12.4	18.7	17.0	18.0	14.5	19.3	17.8
38	Transmission type (0 = automatic, 1 = manual)	--	0.	0.	0.	0.	1.	1.	1.	1.
39	Final drive gear ratio	--	4.30	5.08	4.40	3.93	6.71	6.71	4.72	6.83
40	Final drive gear efficiency	--	0.98	0.90	0.95	0.95	0.95	0.95	0.97	0.98
41	Number of gear ratios	--	4.	2.	3.	3.	5.	5.	5.	8.
42	Transmission efficiency	--	0.98	0.90	0.95	0.95	0.95	0.95	0.95	0.95